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The advantage of standardisation as a management instrument in companies

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ABSTRACT (Maximum 200 words)

The aim of this research project is to illustrate the strategic potential in-company standardization has.

First some relevant definitions are given. Then current typologies of competitive strategies are discussed with regard to their suitability for the following working steps. In the third chapter functional strategies are derived which implement the competitive strategies within the company. In the next chapter a closer look at different in-company standards is taken. Then some examples are given on the use of in-company standards which support the competitive strategies described in the fifth chapter. Subsequently the results from a company inquiry provide an overview of the relevance in-company standards in the sector of mechanical engineering presently have. In the seventh chapter the optimum standardization mixes for the competitive strategies of cost leadership and differentiation are identified and discussed. Finally the results of this research project are summarized and a brief outlook on further possible research is provided.

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1 Introduction

The advancing liberalisation of global markets is influencing the actions of enterprises with national and international operations to an increasing extent. Liberalisation offers many enterprises the opportunity to open up new sales markets; however, at the same time this results in an intensification of competition between competing enterprises at the global level. In order to survive on the market in the long term, enterprises are therefore forced to adapt their internal structures and processes to the dynamic and discrete competitive conditions. Here the selection and efficient in-company implementation of a competitive strategy is of considerable importance as this assures long-term company success. In-company standardisation[1] offers numerous opportunities to support competitive strategies in a sustainable manner and thus represents an efficient instrument for strengthening the competitiveness of enterprises.

The aim of this research project is to illustrate the strategic potential in-company standardisation has.

First some relevant definitions are given. Then current typologies of competitive strategies are discussed with regard to their suitability for the following working steps. In the third chapter functional strategies are derived which implement the competitive strategies within the company. In the next chapter a closer look at different in-company standards is taken. Then some examples are given on the use of in-company standards which support the competitive strategies described in the fifth chapter. Subsequently the results from a company inquiry provide an overview of the relevance in-company standards in the sector of mechanical engineering presently have. In the seventh chapter the optimum standardisation mixes for the competitive strategies of cost leadership and differentiation are identified and discussed. Finally the results of this research project are summarised and a brief outlook on further possible research is provided.

2 Definition of relevant terminology and analysis of current typologies of competitive strategies

2.1 Definitions

Standards represent the results of a process of creating conformity. In the following text this very general definition of standards or standardisation is restricted to the in-company sphere of enterprises and is further specified in this context. In order to formulate a definition for in-company standardisation, it is necessary to clarify the general approaches to defining

[1] As a matter of principle, within the context of this application for renewal, the term ‘standardisation’ is understood to mean the process of producing uniformity. Consequently, a ‘standard’ is a selection of certain alternatives from a range of options aimed at solving a certain problem, e.g. of a technical nature. They are not to be confused with those standards published in written form by standards-setting organisations such as the Deutsches Institut für Normung e.V. (DIN e.V.) for example.

standardisation with respect to the specific internal features of enterprises. Hence, to start with, a definition of enterprises is given from a business administration viewpoint:

An enterprise is an autonomous economic unit that, by combining the production factors of human labour, production resources and materials, pursues the objective of achieving a business profit through the production of goods or provision of services[2].

Incorporating Gutenberg's business definition of enterprises yields the following definition for in-company standards:

In-company standards are drawn up by authorised staff and include features and operating procedures for recurring sequences within the value-added process for the production factors within them as well as for the goods and services.

In addition to defining company standards, it may also be useful to illustrate the scope of the effectiveness or validity of company standards. As a result, hierarchical levels of an enterprise or group are identified which are not only relevant for the investigation but also provide a first insight into the variety and comprehensive character of company standards. In an analogous manner, the different scopes of validity for company standards can be projected onto the four hierarchical levels of a corporate group like figure 1 shows.

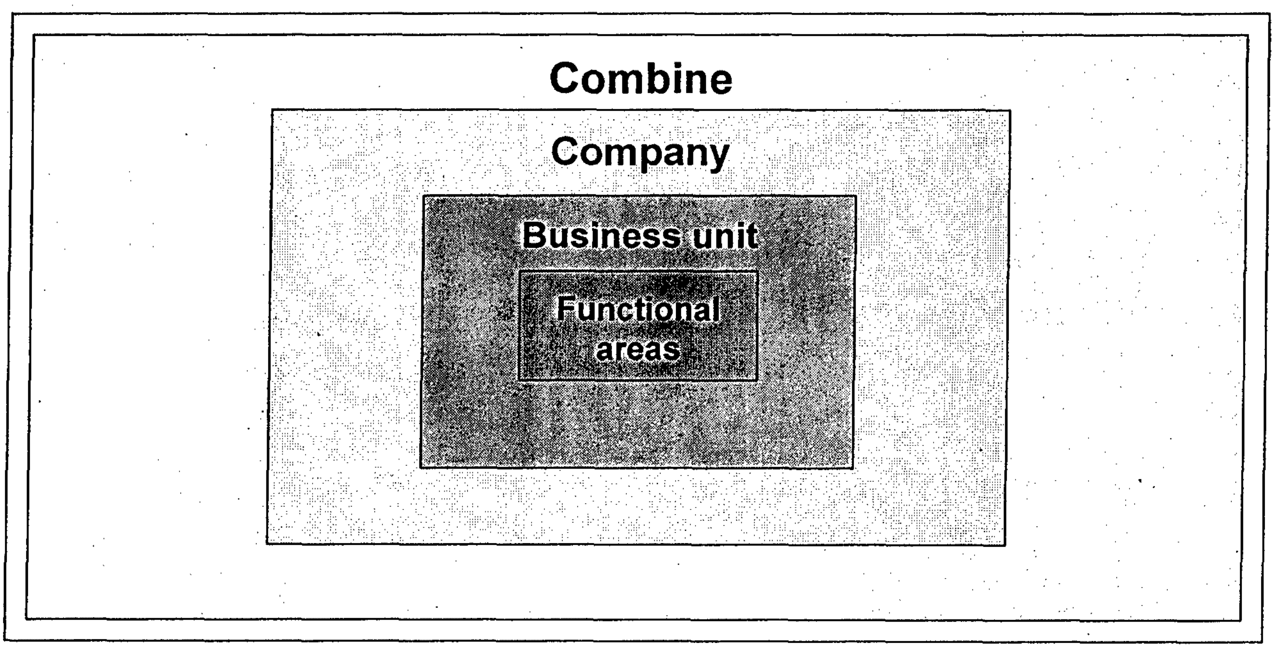

Figure 1: Hierarchical ranges of validity for company standards[3]

To give some initial insight into the subject and problems of in-company standards, they are illustrated in the individual hierarchy levels.

[2] Cf. Hansmann (1994), p. 2.
[3] Based on Adolphi (1997), p. 34.

Company standards with a generally valid character within a corporate group include for example binding rules governing the submission of accounts[4]. One example that might be mentioned for the corporate division is the uniform regulation of working hours. In business fields where customers expect a qualitatively high-value product, efforts may be undertaken to gain certification to the ISO 9000 series. In the functional departments the spectrum of design guidelines within the field of development and design extends from hygiene standards in production through to safety standards when dealing with material production factors and products. It becomes particularly apparent in the functional range that in-company standards occur in a very diverse range of variations[5].

The large number of company standards makes it necessary to limit the content of this work if is to remain within its intended scope. For this reason only those company standards will be considered that can be shown to have, at least under certain in-company conditions or structures, a significant effect on corporate success.

2.2 New approaches to systematizing the concept of strategy in the company environment

In academic literature there is hardly any expression for which more definitions can be found than that of strategy. Consequently, there is a need to define this expression in terms of its meaning in the company environment[6].

Initially six different definitions of strategies relating to business administration are given, which are then discussed with regard to the aims of this research project[7].

1. Strategy as a self-contained, standardised and integrated design pattern for decisions.

This approach defines strategy in a fairly general form as a basis for a universal and integrated design for an organisation as a whole[8]. In this case the strategy ensures the necessary organisational conditions for the managerial actions. Moreover, strategic patterns are employed if discontinuities appear within the company. These may for instance take the form of personnel changes in management or may be triggered by external influences. Hence a strategy is also a pattern of acting directives, if a new orientation for the company in principle is necessary.

---

[4] Cf. Colbe (1984).

[5] This may also be regarded as evidence of the interdisciplinary character of standardisation.

[6] General approaches to the typology of the term strategy can be found in Hanker (1990), p. 47ff. or in Mintzberg's publications (1985, 1987a, 1987b, 1987c).

[7] Based on Hax/Maljuf (1991), p. 2ff.

[8] This definition is for example used by Mintzberg (1987c).

2. Strategy as an instrument for determining sectors in which the companies act.

Here a strategy not only determines the selection of sectors or markets, but may also determine the target growth within a sector/market and reply to questions of diversification or concentration within the competitive markets. Here the crucial strategic question for the management: "Which sector are we in?" and "Which sector do we want to be in?"
Empirical surveys of an expert group have shown that this ostensibly trivial question could not be answered unambiguously[9].

3. Strategy as an instrument of differentiation to separate management tasks in the fields of company, business unit and functional area.

The instances[10] in the hierarchical levels of the company organisation have different ways of influencing the internal design of a competitive strategy. Senior management has most of the relevant information required for making decisions on competitive strategy. Consequently, the tasks resulting from this for senior management are to be found in decisions on proposals that originate from lower hierarchy levels, such as business units or functional areas. Furthermore, senior management has to identify and exploit possible synergistic effects between different but related business units and allocate all kinds of resources in the best possible way. The management of the business units is responsible for the design of their divisions with the existing resources. The responsible management in the functional areas is in charge of designing the departments involved in the value-added process[11].

4. Strategy as an instrument to design the organisational structure, taking account of long-term objectives, action programmes and available resources.

This definition is a classical interpretation of the term strategy[12]. In this case strategy is seen as an instrument for planning the long-term objectives of a company, for determining action programmes and allocating the necessary resources. This pragmatic approach corresponds to the "structure follows strategy thesis". Under the term strategy this thesis subsumes the successive internal implementation of a competitive strategy. The implementation process comprises the formulation of company objectives, the implementation of the necessary arrangements in the functional areas as well as the allocation of existing resources. In this connection the demand for a consistent strategy is stressed, because otherwise the combination of objectives and functional strategies, on the one hand, and the allocation of human, financial, technical and physical resources, on the other, is not possible.

[9] Cf. Hax/Majluf (1991), p. 3.
[10] In business management theory an instance is used to mean offices that have directive power over other offices. Cf. Schreyögg (1998), p. 132.
[11] The three strategy levels in companies are recognised by various authors. Examples to be mentioned at this instance are Andrews (1980), Ansoff (1965) and Vancil/Lorange (1975).
[12] The most significant proponent of this interpretation is Chandler (1962).

5. Strategy as a response to external chances and risks as well as to internal strengths and weaknesses in order to achieve a competitive advantage.

This definition based on Michael E. Porter describes strategy as a response to external competitive forces and internal strengths and weaknesses to ensure long-term company success compared with other competitors from the same sector. This procedure to analyse the competitive forces is aimed at determining the best strategy for a company or business unit. Porter emphasises that a competitive advantage is influenced by external and internal factors. The external competitive forces are shown in figure 2.

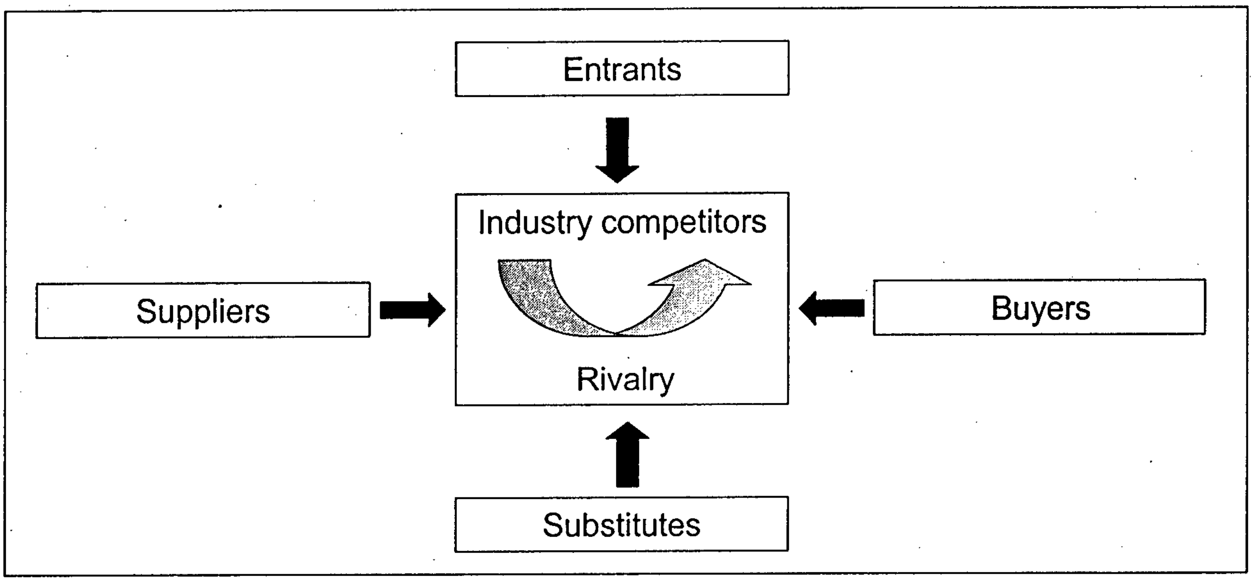

Figure 2: Competitive forces[13]

Internally, the aim is to increase strengths and if necessary correct weaknesses. Strategy is not seen as a passive instrument in terms of a response to external changes. Instead, a strategy is used to influence the external competitive forces.
Within this framework three main aspects can be identified that are relevant for the design of a competitive strategy:

- The business unit as a central object of analysis.
- The structure of a sector, which determines the general trends within it.
- The internal capabilities that influence the selection of a competitive strategy.

[13] From Porter (1980), p. 4.

6. Strategy as a criterion for the intended economic and non-economic contributions of a company to its stakeholders.

The relationship of a company to its stakeholders is another aspect in the strategy-defining process. In this context the term represents all the persons or groups that have direct or indirect advantages or disadvantages as a result of the company's activities. For instance shareholders, managers, employees, customers, suppliers, creditors, associations of local authorities but also residents belong to the group of stakeholders.
By taking account of stakeholders in the process of formulating and implementing a competitive strategy, a much greater target group is being included than would be the case if attention were merely focused on the group of shareholders or owners for example. As a result, the term "strategic" (in the sense of long-term) can be much better satisfied than it would be if the company objectives merely concentrated on the demands of the shareholder (maximizing dividends and share prices). Achieving a reasonable profit is certainly the primary objective of any company. However, by focusing on short-term profits a company runs the risk of jeopardizing its competitive position in the long term. A balanced consideration of all stakeholders reduces this hazard. External competitive forces such as customer satisfaction[14] are also included in the "stakeholder approach".

Except for definition (2), all other definitions show at least implicitly that strategies in the corporate field are targeted at the interface "organisation/environment".
The theoretical validation of our research approach is of fundamental importance for this work and is given particularly in connection with definitions (3) and (4). This will involve confirming the implementation of a competitive strategy by means of functional strategies within the context of the "structure follows strategy thesis". Whether the internal implementation process is accomplished by a "bottom-up" (3) or "top-down" (4) approach has no influence on the research procedure, because analysis of the internal decision-making does not form part of this work.
Theoretical validation of the research approach will be followed by a survey of strategy levels in companies, which will further define the subject matter of the research topic.

2.3 Business management levels and corresponding types of strategies

In business management literature strategies are always classified into four levels[15]. The strategies involved are those within each sector (industrial policy), the entire company or group (corporate strategy), the business unit (competitive strategy) and the functional area (functional strategies).

[14] Some authors already specify customer satisfaction as the true decisive criterion in selecting the competitive strategy. Cf. Zahn (1990), p. 15.
[15] Cf. for example Hofer/Schendel (1978), p. 14f. and Kotha/Orne, (1989), p. 212.

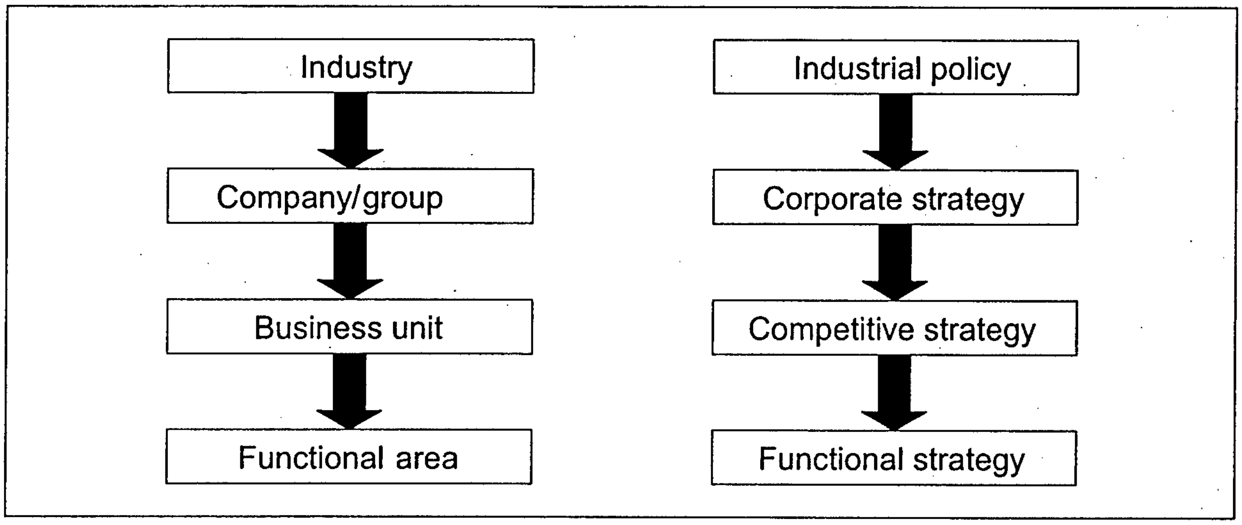

Figure 3: Business management levels and corresponding types of strategies

The industry level includes associations and government bodies as well as companies. The decisions that are made in this environment fall into the category of industrial policy. The topics discussed in this environment are those such as geographical and financial policy, questions of import and export arrangements, etc. Typically industrial policy decisions are capable of being directly influenced by external competitive forces, whereas in the subsequent strategy levels autonomous decisions are the rule, because external competitive forces only have to be considered indirectly.

Others issues that fall within the scope of corporate strategy are those concerning the general orientation of companies, predefinition of the market segments in which the company wants to operate and the integration of specific strategic business units[16].

Strategic calculations at the business unit level are concerned with setting market-specific borders and internal orientation. The main focus here lies in choosing a competitive strategy that ensures long-term success in the market.

In the functional area of a company the competitive strategy pursued is implemented by defining functional strategies. In this connection, measures are derived from the functional strategies for the specific units in the value-added process (e.g. procurement, production, marketing and distribution) so that they offer the best support for competitive strategy and hence ensure the long-term success of the company.

Having set the limits for the subject matter and defined the competitive and functional strategies, we now aim to determine the area for which these strategies are valid. The objective here is to clarify the degree to which company-specific features have an influence on the internal implementation of competitive strategies by means of functional strategies. The lower the influence of company-specific features on the determination of competitive and in particular of functional strategies, the more significant the future results will be regarding the assessment of in-company standards in different industries and company types.

[16] On the subject of external standardisation strategies in this level, see Borowicz/Scherm (1999).

2.4 Scope of validity for competitive and functional strategies

The scope of validity for competitive and functional strategies in economics literature has been the subject of heated discussion for many years now. Three concepts have arisen from this discussion and these are described below.

The proponents of the **atomistic** concept argue that, owing to the dynamism and discontinuity of markets as well as differences specific to individual industries and companies, no universally valid statements can be made to cover the field of focal business. This also applies to the field of competitive and functional strategies[17].
In contrast, approaches based on **contingency theory** postulate a higher level of generalisation for competitive and functional strategies. Reference here is made to the impact of factors from contingency theory such as sectoral structure, market share or product life cycle[18].
Generic strategic approaches presuppose that the basic pattern of the business units existing within the market segment is independent of the industrial sector[19].

As shown later in this report, competitive strategies in particular have a generic character. The analysis and selection of a suitable typology for competitive strategies is the main focus of the following chapter.

2.5 Typologies of competitive strategies

2.5.1 Competitive strategies according to Porter

The following typology of competitive strategies is based on Michael E. Porter and covers three generic competitive strategies. He calls these strategies cost leadership, differentiation and focusing.
Besides these definitions an illustration of possible negative influences on company success is given to facilitate a critical appraisal.

Cost leadership: A company structures its value-added process in such a way that the production process is permanently cheaper than the production processes of competing companies. The product demand in these market segments is normally elastic.

[17] Cf. for example Uyterhoeven et al. (1973).
[18] Cf. for example Hambrick/Lei (1985).
[19] Cf. for example Porter (1988).

Risks:

- Current investments and existing know-how can fall in value due to technological progress.
- New competing companies are able to achieve the same cost level by imitation of processes and investment in modern production facilities.
- Inability to recognise necessary shifts in products or market because the attention is concentrated too intensely on costs.
- The occurrence of cost increases that reduce the company's ability to maintain a sufficiently high difference between prices in order to compensate for any existing differentiation advantages of competing companies.

Differentiation: A company is in a position to distinguish its own products from those of its competitors. The producers of differentiated products assume that their target has a relatively inelastic buying pattern.

Risks:

- The cost differences between the differentiated products of a company and cheaper products are so high that the special features and performance of differentiated products do not meet with sufficient acceptance from potential customers. At the beginning of the seventies Japanese motorbike manufacturers captured great market shares in this segment by having considerably lower selling prices than their more renowned European and American competitors for instance.
- The demand for the differentiated feature falls. This may happen if customer preferences change.
- Companies whose differentiation advantage is based to a large extent on a renowned brand name may lose their market share due to plagiarism.

Focusing: In this category the company restricts itself to those business units in which it is especially competitive. Focusing on special market segments or core competences is generally accompanied by variety reduction in parts held by the company.

Risks:

- There may be a decrease in the difference between the products and services demanded by the strategic customer group, on the one hand, and by the entire market, on the other.
- Competitors open a sub-market within the target group on which the company is focused.

Porter first introduced these three competitive strategies in his book entitled "Competitive Strategy"[20], which was published in 1980. In that edition all three strategy types were regarded as absolutely independent (singular), i.e. as non-combinable. Figure 4 again shows the strategies discussed.

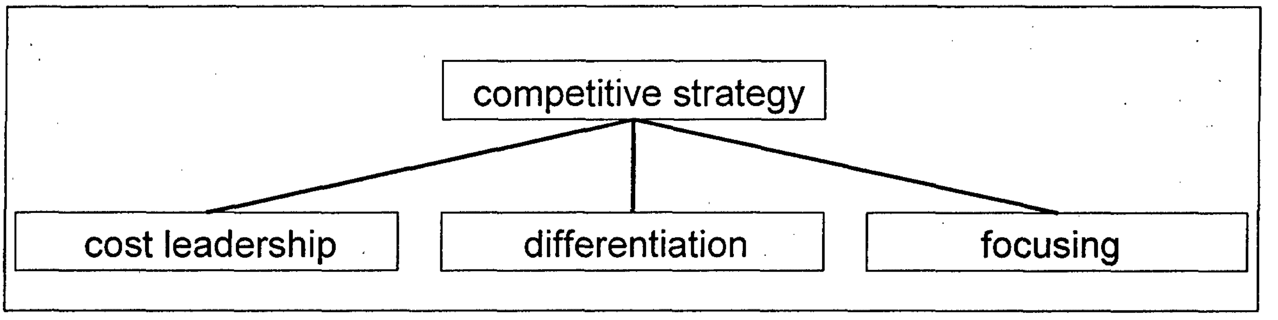

Figure 4: Singular competitive strategies

The autarky of the competitive strategies presented in figure 4 has been adjusted by Porter in his revised typology from 1985, so that the following matrix now applies.

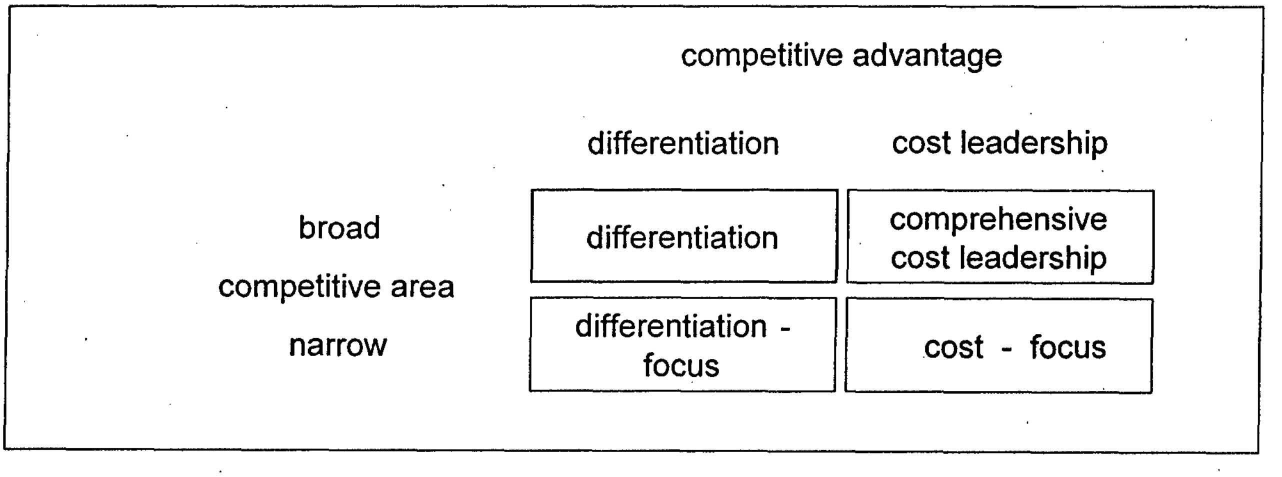

Figure 5: Porters current typology

The figure highlights the difference from Porter's first typology. In figure 4 all three competitive strategies are rated equally and there is no way of combining the three types. In his current typology focusing is no longer an independent strategy. Instead, the stress is placed on the fact that a company can survive amongst the competition if it achieves cost or differentiation advantages. The former competitive strategy of focusing is used in his current typology merely as a criterion to define the boundaries of the competitive area. In this case the benchmark for this demarcation of the competitive area is given by the company's share of customers in the market segment. Classification into broad and narrow competitive areas creates four competitive strategies. These are "differentiation" (broad) or "differentiation-

[20] Cf. Porter, M.E. (1980).

focus" (narrow) and "comprehensive cost leadership" (broad) or "cost-focus" (narrow). Porter continues to reject the possibility of generating hybrid strategies through a combination of differentiation and cost leadership.

To justify his typology, Porter bases his argumentation on three theses.

Convexity hypothesis [21]

The strategy of cost leadership is normally connected with a high market share, because economies of scale can be achieved in the fabrication process of standardised mass products. One tangible example of this can be seen in the learning-curve effect. The growth in experience is accompanied by a doubling of cumulative production output, which in turn leads to a decrease in the unit cost of between 20-30%[22].

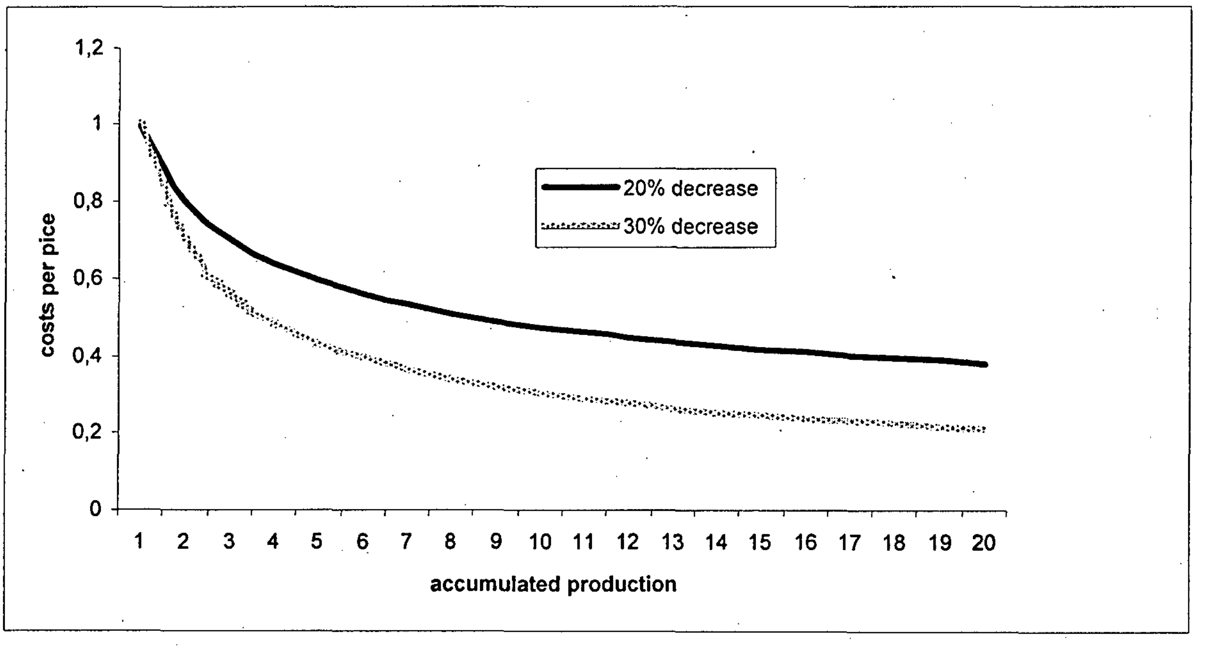

Figure 6: The learning-curve effect

In contrast to this, a differentiation strategy is often associated with small market shares, because Porter assumes that an exclusive brand name is not compatible with high market shares[23].

[21] In the specialist literature the term market share hypothesis is used as well as convexity hypothesis. For more details on this subject, see also Barzen/Wahle (1990), p. 107.

[22] Cf. for example Henderson (1984), p. 19, Bauer (1986), p. 1ff., Kloock et al. (1987), p. 3 ff. or Hentze, et al. (1993), p. 171. A list of published contributions on the learning curve is given by Hammerstein (1987), p. 95ff.

[23] Cf. Porter (1988), p. 66.

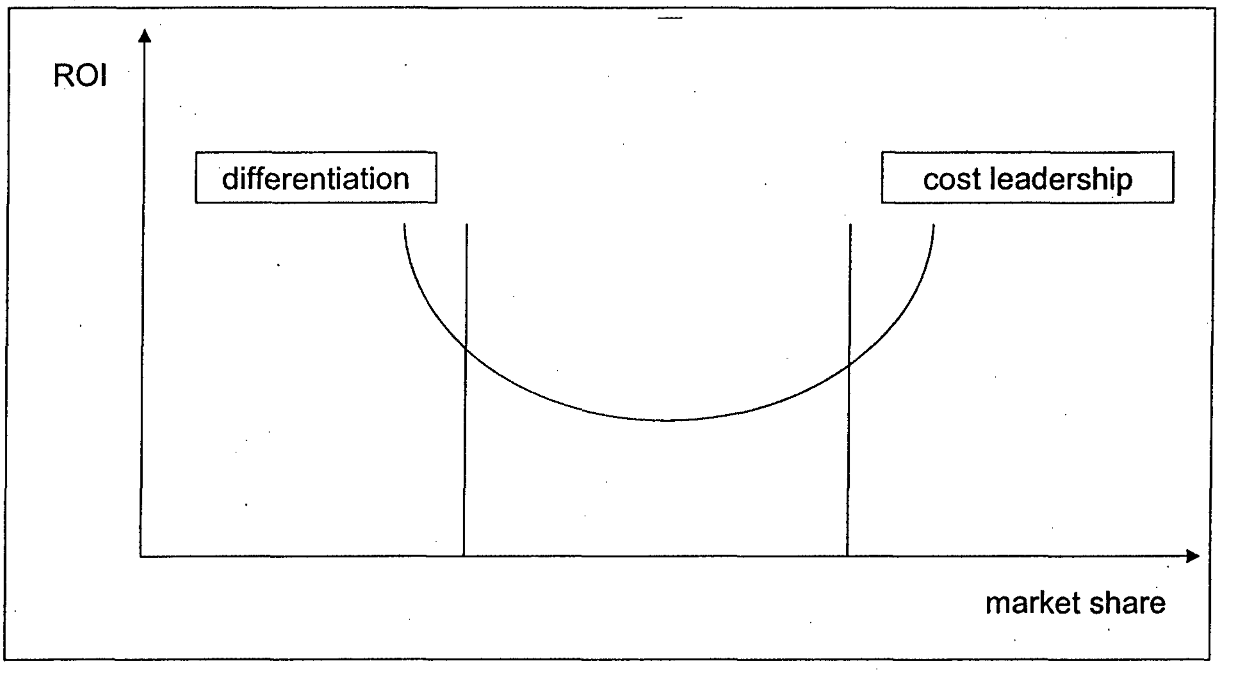

Figure 7: The convexity hypothesis

Figure 7 illustrates Porters Hypothesis, which states that only a singular strategy can guarantee a high ROI (return on investment). The convex shape of the graph is the origin for the term "convexity hypothesis". The implicit assertion, that cost leadership and differentiation are based on unequal market shares confirms Porter's thesis that cost leadership and differentiation are incompatible.

The sustainability of the learning curve effect has been the subject of much controversy in the specialist literature[24]. For instance, several authors claim that the learning-curve effect only has an effect of reducing unit costs in the initial phase of new processes and structures. When a specific accumulated production output has been achieved, the learning curve effect has only a marginal impact. In fact, there is a stagnation of the unit costs at a specific accumulated production output. This statement is based on various empirical studies, which took place as long ago as the mid-sixties[25]. The age and the complexity of the production process may be viewed as two of the important influential factors here. The cost-reducing impact of the learning-curve effect is strongest when the processes are new and complex. A significant lowering of the unit costs can also be achieved for less complex processes. In the case of established processes, where "established" may be seen as indicating a high accumulated production output, only a marginal reduction in the unit costs is observed from learning effects. Here the grade of complexity has no significant impact[26].

[24] Cf. Trux et al. (1988), p. 131-137 or Mauthe (1984), p. 318ff.
[25] For more information see also Alchian (1963), Baloff (1966) or Hall/Howell (1985).
[26] Cf. Hill (1988), p. 406.

Age of process	New process	Significant learning over a short time period	Significant learning over a long time period
	Established process	No significant learning	No significant learning
		Low complexity	High complexity
		Complexity of the process	

Figure 8: The learning curve effect and processes[27]

Other authors attach greater significance to the relative size of a company (maximum output) in reducing unit costs. They stress the importance of fixed costs, which have a lower influence on the unit costs in large companies than in small and medium enterprises[28].
However the influence of the company size on unit cost varies considerably between different industries. In an empirical investigation Scherer et al. identify the level of minimum cost-efficient size (MCS) of companies in different industries and illustrate the percentage increase of the unit costs for a reduction in market share of 67 percent[29].

Industrial sector	MCS in the US market in per cent	Percentage increase in costs with 1/3 market share
Breweries	3.5	5.0
Tobacco industry	6.5	2.2
Textile industry	0.2	7.6
Paints & varnishes	1.4	4.4
Oil refineries	1.9	4.8
Shoes	0.2	1.5
Glass bottles	1.5	11.0
Cement	1.7	26.0
Steel	2.6	11.0
Ball bearings	1.4	8.0
Refrigerators	14.1	6.5
Batteries	1.9	4.6

Figure 9: Minimum cost-efficient size, market share und increase in the unit costs below the MCS[30]

The results illustrated in figure 9 disagree with Porter's convexity hypothesis, because in only three of the twelve industries analysed does the MCS lie above three percent of the US-market share. Except for the steel, cement and glass industries, the forecast cost increases are relatively low. The existing production structure is an important factor in each case. These three industries predominantly make use of continuous flow and controlled production methods. The amply dimensioned manufacturing plants are especially designed for one

[27] From Hill (1988), p. 407.
[28] The authors Harrison/St. John (1998) even explicitly exclude the learning curve effect from their representation of economies of scale. For instance, Harrison and St. John quote the personnel costs of senior executives and construction costs of buildings. Cf. Harrison/St. John (1998), p. 145.
[29] Cf. Scherer et al. (1975), p. 80ff.
[30] Cf. Scherer et al. (1975), p. 94ff. The minimum cost-efficient size is determined by the relation between companies that achieve a certain level of output and the total domestic sales figure in each case.

manufacturing process, so that when there is a decline in market share, idle times arise in the production, which lead to a sharp rise in average unit costs. There are numerous similarities between the specific characteristics of the companies in these three industries, which have strong rises in average unit costs:

- homogeneity of products,
- mass production through continuous flow or controlled production methods,
- manufacturing plants of high capacity and low flexibility,
- high infrastructure requirements to deal with the transport of raw materials and products,
- significant sunk costs,
- high transport costs make it difficult to serve global markets.

These characteristics may act as decision criteria for the strategic alignment of a business unit. The homogeneity of the products prevents effective product differentiation and thus lowers the prospects of success for a hybrid competitive strategy. The manufacturing plants must exhibit a high capacity and a high degree of capacity utilisation to ensure cost-effective production. The raw materials needed for production have a high weight (iron ore, quarry sand, lime and clay). Raw materials are mostly delivered in large lots. Consequently, powerful plant with a high handling capacity is needed; involving considerable investment costs (sunk costs). If these plants cannot be sufficiently exploited, these fixed costs place a higher-than-average burden on the unit costs. This state is verified by the data documented in the chart and can be employed to support Porter's convexity hypothesis.
Some of the rises in costs for the remaining nine industries lie considerably below 8%: the minor rise in costs of 1.5% in the market segment for "shoes" is particularly notable. With an associated cost-efficient market share of 0.2%, this is one industry in which the convexity hypothesis can obviously not be quoted as an argument against the economic sustainability of hybrid strategies. As a result this disproves the general validity of the convexity hypothesis.

Concentration hypothesis

Porter introduces the so-called principle of concentration as a further argument for the singularity of competitive strategies[31]. The principle of concentration states that a company has to concentrate its resources, structures and especially its functional strategies on a competitive advantage category (differentiation or cost leadership), in which it aspires to a leading position. If a company violates this principle by implementing a hybrid strategy, it will meet competitors who, by virtue of their singular competitive strategies, have either a cost or a differentiation advantage. According to Porter, this cannot lead to disproportionately successful business.

[31] According to Simon (1988), p. 471ff.

Consistency hypothesis

The consideration of differentiation or cost leadership in a hybrid competitive strategy makes it more difficult to determine and implement functional strategies because conflicts of objectives often occur. This state of affairs is described by the principle of consistency. The principle of consistency is thus an additional argument for the incompatibility of differentiation and cost leadership in a hybrid competitive strategy (mixed strategy).

Porter uses the quoted theses to justify the structure of his typology. If later results of research are to remain unambiguous, timeless and thus generally applicable, the typology selected by Porter must have the following additional attributes:

1. A means of clearly deriving functional strategies from the competitive strategy for the company's functional level.
2. Collective exhaustiveness (all competitive strategies must be clearly assignable to one of the four categories).
3. Mutual exclusion (every competitive strategy can belong to only one category).
4. Timelessness.

1: Through the strict division of differentiation and cost leadership in competitive strategies Porter's typology enables the functional strategies to be derived within the framework of the consistency principle in an unequivocal manner.

2: It has to be stated, that by no means all competitive strategies can be classified with Porter's typology. The automotive industry serves as an example here. Surely Rolls Royce comes within the limits of differentiation-focus, BMW within the limits of differentiation and some Japanese manufacturers within the limits of cost leadership. In the case of Ford or Opel, however, no unambiguous classification is impossible because these companies have achieved their success both by price and by differentiation. These competitive strategies can therefore not be unambiguously classified in Porter's typology.

3: Porter's typology forms categories without common intersections if the parameters (narrow and wide) are clearly defined. Hence this criterion is fulfilled.

4: Although product life cycles are becoming shorter in many industries, particularly in the case of products with a prominent technological component, competitive strategies have a timeless character. This statement is based on the fact that customers decide on the basis of the relation between costs and benefit when purchasing goods or availing themselves of services. This relation is always determined by the costs of production (cost leadership) and the defined product features (differentiation).

The unsatisfactory characteristic of Porter's singular typology concerning the criterion "collective exhaustiveness" demands an analysis of hybrid typologies. As far as this research project is concerned, this should then be followed by selection of the optimum typology for competitive strategies.

2.5.2 Competitive strategies according to Wright et al.

The typology presented in the following was published by Wright, Pringle und Kroll in 1992. In contrast to Porter, these authors advocate the existence of hybrid competitive strategies and quote practical examples which critically analyse Porter's typology. Wright et al. give several internal activities, which take account of both costs and differentiation aspects at the same time and hence contradict Porter's argumentation concerning the consistency hypothesis [32]. The following examples are some of those presented by Wright et al. to demonstrate how companies can produce differentiated and cost-efficient goods at the same time:

1. focus on quality
2. innovative processes
3. innovative products
4. system innovations
5. leverage effects by means of differing skills

1: A consistent, continuous improvement of the product quality in all functional company segments not only increases the quality but also reduces the costs incurred by disposal, guarantee obligations and after-sales service.

2: Innovative processes can often bring about cost-efficient production processes. In an ideal case the degree of differentiation can be increased too. In this connection Wright et al. quote the example of a computer manufacturer. In this company a flexible assembly system was installed for $20,000,000. This investment had amortised itself after one year. Furthermore, the reject rate in final inspection and the number of guarantee claims sank considerably[33].

3: Product innovations can have a cost reduction effect too. Phillip Morris was the first company to develop a filter tipped cigarette and then later cigarettes with low tar and nicotine values. Although these activities aim primarily at a higher differentiation, a positive side-effect lies in the reduction of costs, because the tobacco used for these kinds of cigarettes can be of lower quality and is cheaper to purchase.

[32] Cf. Wright et al. (1992), p. 99ff.
[33] Wright et al. quote an increase in product quality of 90%, although this value cannot be uniquely allocated.

4: System innovations in the value-added chain are another instrument to support different competitive strategies. Through outsourcing some companies have managed to achieve a reduction in costs as well as an increase in product quality[34].

5: Porsche is active in the development and design sector and also works for automobile manufacturers, such as General Motors, which are very important for supplier companies. Consequently, suppliers offer Porsche their components at similarly low prices to those for their bigger customers with the aim of supplying large automobile manufacturers as well.

On the basis of these practical examples, Wright et al. are of the opinion that cost leadership and differentiation combined into a hybrid competitive strategy can definitely be a successful strategy. Figure 10 demonstrates this typology once more.

	competitive advantage		
	differentiation		cost leadership
broad	differentiation	differentiation and cost leadership	comprehensive cost leadership
competition area			
narrow	differentiation-focus	cost-differentiation-focus	cost-focus

Figure 10: Typology according to Wright et al.[35]

The typology of Wright et al. certainly includes the advantage that it takes account of a major spectrum of competitive strategies[36]. In this connection once again reference is made to the examples of Opel and Ford (hybrid strategy, which included cost and differentiation aspects). The disadvantage of this typology can be seen in the problems of applying hybrid competitive strategies to the functional divisional level of a company.

2.6 Choosing a typology of competitive strategies

Apart from clarifying the professional terminology, the main focus of this chapter lies in the appraisal of competitive strategies and in choosing an appropriate typology. Even though Porter's typology is not entirely convincing, it is used as the starting point for determining functional strategies in the remainder of this work. Although Porter's typology has the disadvantage that it is not collectively exhaustive, this disadvantage is not as great as the

[34] Refer also to Gluck (1980).
[35] This work does not go into any further detail on the multiple competitive strategies quoted by Wright et al. Multiple strategies combine at least two of the six forms of strategy from figure 10. For multiple strategies see Wright et al. (1992), p. 106ff.

extreme difficulty in deriving functional strategies from the hybrid competitive strategies from Wright et al. In this context, it should also be pointed out that subsequent results using Porter's typology can be transferred to companies with hybrid competitive strategies. The theory of colours serves as an example here: mixing the three fundamental colours (yellow, red, blue) enables all other colours to be generated. By combining generic functional strategies, the management concerned is able to implement its hybrid competitive strategy within the company. The exact kind of implementation naturally depends on the subjective preferences of the respective management and is beyond the scope of this project.

Summary chapter 2

In this chapter definitions of the relevant professional terminology were given. In this study the character of in-company standards can be described as follows:
"In-company standards are drawn up by authorised staff and include features and operating procedures for recurring sequences within the value-added process for the production factors within them as well as for the goods and services."
Furthermore, six different approaches to modelling the concept of strategy in the company environment were discussed with regard to the aims of this research project. In this connection two definitions have turned out to be especially useful for the given research project. The implementation of a competitive strategy by means of functional strategies within the context of the "structure follows strategy thesis" is validated by these two definitions. Following on from this, two different typologies of competitive strategies were described together with an examination of their suitability in terms of the working steps to be undertaken. It was shown that functional and competitive strategies in particular have a generic character. This ensures that the action pattern of business units is independent of the industrial sector and so the research results are universally valid. Porter's current typology with the competitive strategies of cost leadership and differentiation was selected for the use in this study because it excludes hybrid strategies and enables the derivation of functional strategies stemming from competitive strategies. The exclusion of hybrid strategies has been shown to portray a simplified and even fuzzy illustration of reality. But in consideration of the existing advantages this issue is of secondary importance. Consequently, the competitive strategies examined are limited to cost leadership and differentiation. Furthermore, Porter's argumentation is based on three popular hypotheses which are, however, all open to criticism. In particular the so-called "convexity hypothesis", which partly bases on the much-debated learning-curve effect, exhibits some weaknesses.

[36] A similar typology has also been developed by Miller/Dess (1993), p. 565.

3 Analysis of functional strategies

Following the selection of Porter's typology, this chapter considers the internal process of implementing competitive strategies by deriving functional strategies. Starting from the competitive strategy being pursued, the strategic consequences are successively defined in greater detail by the formulation of functional strategies.

In the subsequent course of this study the functional strategies listed for the company divisions of research & development, procurement and production will form important criteria for designing an optimum standardisation mix. The standardisation mix comprises in-company standards that support functional strategies with complementary characteristics in terms of the hierarchically superior competitive strategy. The in-company standards with a significant impact on strategies inside the functional and business segment will be analysed in the remaining research timeframe. After this optimum standardisation mixes will be drawn up for the competitive strategies of differentiation and cost leadership.

3.1 Tasks of functional strategies

In general functional strategies fulfil three main tasks[37].

- a detailing function,
- a coordinating function and
- a planning function.

Detailing function:
Functional strategies transfer the guidelines of a competitive strategy in detail to the relevant functional area of a company. This involves drawing up a specific functional framework for the operational management, which results from a practical interpretation of the competitive strategy.

Coordinating function:
Functional strategies also fulfil an important coordination task in companies. On the one hand, the interactions between all of the production factors existing within a functional area are defined. Consequently, this coordination function has a vertical direction of thrust. In addition, horizontal coordination leads to a harmonisation of the processes within the functional areas in order to achieve the best possible match with the superior competitive strategy.

Planning function:
The functional strategies form the interfaces between the competitive strategy and its operative implementation in the different divisions. They define directives that provide the

[37] See also Pümpin (1980), p. 50ff.

framework for the design of the functional divisions by the responsible manager. Against this background, the functional strategies are used for determining the operative planning.

Now that the general range of tasks for functional strategies has been described, it is necessary to give a comprehensive description of common functional strategies. Against the background of in-company standardisation, the main focus of the investigation is on the company divisions of research & development, procurement and production. Other classical divisions like marketing, human resources and finances are consciously omitted, because the in-company standards considered later on only have a marginal effect on these functional areas.

3.2 Functional strategies in companies

3.2.1 Research and development

Advancing globalisation is causing an increase in competition in nearly all sectors of industry. The ever-increasing pace of technological progress, the change from a sellers' to a buyers' market and the constant diversification of customer preferences are forcing companies to gear their product range to the increasingly dynamic market conditions. Numerous companies are responding to these dynamic market conditions by focusing on the development of new technical solutions, accompanied by a shortening of innovation cycles. As a result, strategic orientation in the field of research and development is becoming increasingly important[38]. Viewed against this backdrop, the formulation of explicit functional strategies is becoming a priority objective for companies to consolidate and enhance their own competitive position. Some authors view the strategic orientation of the R&D department through the use of functional strategies as a problem and cite the following arguments[39]:

- the innovative character in the R&D department is less open to standardisation;
- creativity is restricted;
- it is not always possible to give clear statements on current planning and the applied techniques because of the strong dynamic nature;
- there is a lack of objectives in this functional division.

However, there are good reasons for using the strategic guidelines to design the operational activities in research and development. On the one hand, processes in the various functional divisions require horizontal coordination to ensure optimum design of the value-added process. Furthermore, systematic R&D planning reduces the risk that technological changes and options will be recognised too late in the day and thus reduces the risk of late market entry. Normally research projects are characterised by their long-term nature and high costs. Therefore if research is to be efficient, there is a need to organise the activities by means of

[38] Cf. for example Quinn (1990), p. 147 or Erickson/Maggee (1990), p. 74ff.
[39] From Brockhoff (1988), p. 90ff.

functional strategies to boost the aims of the other functional areas and to support the chosen competitive strategy efficiently[40].

In general the department R&D has three main tasks. While basic research aims at the acquiring fundamentally new knowledge, applied research, which builds on this basic research, focuses on the technical implementation of explicitly defined objectives. In the development process the know-how thus generated is used for the design of new products or for the modification of already existing products. The effects of in-company standardisation have the strongest impact on this range of activities. Hence, the functional strategies are presented below focus on the field of development and design. With reference to a competitive strategy of differentiation or cost leadership, the following functional strategies will provide the basis for an appraisal of in-company standards in R&D in chapter 7 of this work.

Functional strategies for differentiation in research and development:

- gaining advantages through differentiation by means of innovative products,
- development and construction of products that ensure fast and flexible fabrication,
- development of ecologically friendly products and processes,
- development of products with a low susceptibility to failure,
- shortening of research and development time to allow a timely response to shifts in the market in the form of new technologies and products,
- research in the field of advanced technology to serve markets with high expansion rates.

Functional strategies for cost leadership in the field of research and development:

- development and construction of products that ensure high economies of scale in fabrication and procurement,
- development of processes for cost reduction in fabrication and distribution.

Some of the functional strategies presented here have a hybrid character with respect to the competitive strategies of cost leadership and differentiation. Fabricating products of high quality and with ecologically friendly features can for example enable cost advantages to be achieved. The classification of functional strategies carried out here is therefore not always homogeneous. In these cases the primary objective served as the classification criterion.

3.2.2 Procurement

Changes in the procurement markets over the last decade have been characterised by a shortage of important resources, disproportionate price increases, delivery bottlenecks, a

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[40] Cf. Welge/Al-Laham (1992), p. 265.

rising internationalisation and a tendency to concentration of supply[41]. Furthermore, economic changes in sales and production have increased the demands on procurement.

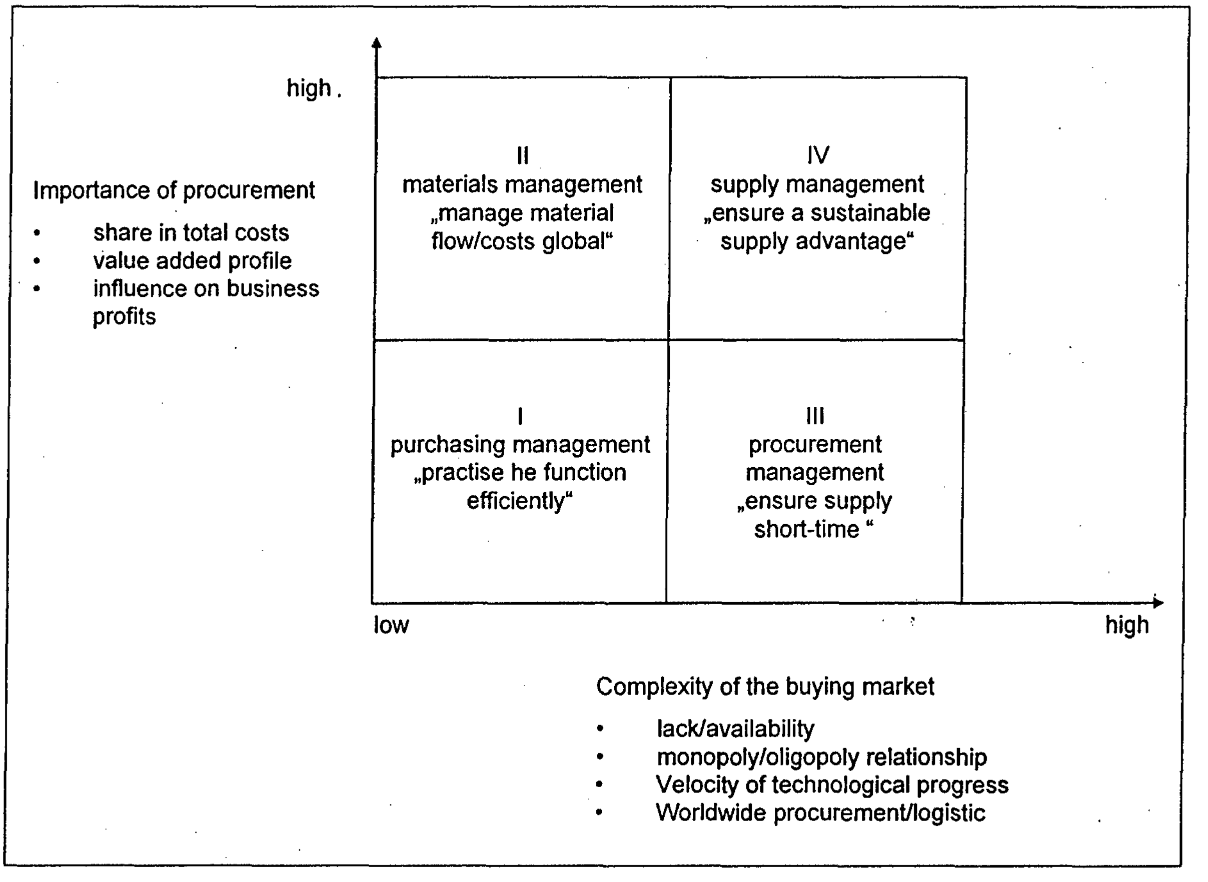

Figure 11: Basic position of the procurement function in companies[42]

The shortening of innovation cycles accompanied by a reduction in the vertical production depth due to companies focusing on their core competence has led to a rise in procurement quantities for many companies. In addition, the growing number of order items, which results from product differentiation measures, is increasing the strategic success potential of procurement. Modern logistic approaches such as the delivery and allocation of the required raw materials and processing aid together with just-in-time or just-in-sequence supply methods demand a high degree of quality and flexibility from both procurement and the supplier. Viewed in this context, a long-term planning approach for procurement using functional strategies would appear to be urgently needed.

The importance of procurement for business success is affected by several external and internal factors. The external factors affect the complexity of the buying market and include the supplier structure, the availability of required materials or the speed of technological

[41] Cf. for example Müller (2000), p. 5.
[42] From Kraljic (1998), p. 482.

progress. The proportion of purchasing in total costs, the impact on business profits and the structure of the value-added process are internal factors[43].

The impact of these factors on the procurement function can be seen in Figure 11. The need for long-term procurement planning, which has strategic guidelines defined by functional strategies, becomes more urgent as procurement becomes more relevant for business success and as procurement markets become more complex.

The following questions normally have to be taken into account when formulating procurement strategies[44]:

- How can the procurement market position be protected?
- How can a maximum degree of flexibility be maintained in the field of procurement?
- How can risks in procurement be spread?
- How can the reliability of supply be improved?
- How can the target quality be guaranteed?
- What significance should be attached to a company's own procurement autonomy?
- How important are partnerships with external institutions?
- How should the internal material flow be organised?

These fundamental questions apply to at least one of three formal objectives of procurement. These objectives are aimed at the reduction of costs, improvement of efficiency or higher autonomy vis-à-vis suppliers[45]. The following functional strategies may be listed as competitive strategies of differentiation and cost leadership.

Functional strategies for differentiation in the field of procurement:

- quality enhancement of raw materials and supplies,
- higher flexibility in the field of procurement and
- higher involvement of suppliers.

Functional strategies for cost leadership in the field of procurement:

- reduction of procurement and storage costs,
- efficient handling of order transactions and
- securing of material provision for the production process.

Here too the classification is open to ambiguity. This particularly applies to the functional strategy of securing higher involvement of suppliers, which in this report is primarily understood to mean the extension of technological cooperation between suppliers and buyers,

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[43] See also Kraljic (1998), p. 481f.
[44] See also Reintjes (1995).

with the company (buyer) using the available know-how of the supplier. Suppliers of this kind take on extensive development services and provide the buyer with access to components of a high technical quality, which in turn facilitate the production of differentiated goods. Cooperation of this form can lead to higher dependency of the supplier and hence to a better bargaining position for the buyer, reflected by lower purchase prices. But this effect has a secondary character, because the main objective of many companies lies in guaranteeing a material supply. There is consequently great interest in an economically healthy supplier[46].

3.2.3 Production

Traditionally production planning has merely pursued tasks of operational planning and control within the production process. However, in recent years the production environment has changed so dramatically that this function also has to be organised on the basis of strategic guidelines. The reasons for this include the increasing incalculability of trends in demand, which calls for high flexibility in the production process, the constant increase in variety of model versions found in some industries and increased demands imposed on quality and delivery time. The functional strategies are primarily targeted at optimizing three fields of activity within production[47]:

Production programme
The production programme determines the products, their characteristics and the lot sizes. In this connection only product groups are considered in the medium-term, while short-term production programme planning deals with all product variants and components. In addition, the production programme manages the date of production and the allocation of required production capacities. In the long-term, production programme planning involves making strategic decisions on production depth and the policy regarding in-house and external production.

Production structure
The determination of production structure is concerned with questions regarding the production technology used, the production capacities needed and the locations of available manufacturing facilities. Research and development activities in the field of production processes are also discussed when the production structure is determined.

Production process
The implementation of the production programme inside the given production structure is a main task of strategic production process planning. Production process planning involves decisions on the type of production process to be employed.

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[45] Cf. Grochla/Schönbohm (1980), p. 34.
[46] Due to the high level of expertise and the high-quality components and systems, the economic situation of suppliers who have close technological cooperation with the company concerned is far better than that of companies that merely supply parts. Cf. Schwalbach/Wolters (1994), p. 39.
[47] For example, see also Zäpfel (1989), p. 115ff.

The strategic guidelines imposed on these three fields of production activity for achieving differentiation or cost advantages can be illustrated by the following functional strategies.

Functional strategies for differentiation in the field of production:

- higher flexibility in the production process,
- reduction of throughput time,
- fabrication of high-quality products and
- fabrication and use of ecologically friendly products and production processes.

Functional strategies for cost leadership in the field of production:

- reduction of changeover activities,
- shorter changeover times,
- reduction of volume of stocks and
- reduction of defective goods.

The here illustrated functional strategies are an important criterion for designing the optimum standardisation mix. The company standards which have a significant impact on functional and competitive strategies are another essential component of the optimum standardisation mix. These company standards are described in the following chapter.

Summary chapter 3

In this chapter, functional strategies and general objectives were established for the competitive strategies of cost leadership and differentiation in the corporate divisions of procurement, research & development and production. In general functional strategies fulfil a detailing, a coordinating and a planning function. The following chart gives a survey of the important functional strategies in the three divisions.

	Cost leadership	Differentiation
Procurement	• reduction of procurement and storage costs, • efficient handling of order transactions and • securing of material provision for the production process.	• quality enhancement of raw materials and supplies, • higher flexibility in the field of procurement and • higher involvement of suppliers.
Research & Development	• development and construction of products that ensure high economies of scale in fabrication and procurement, • development of processes for cost reduction in fabrication and distribution.	• gaining advantages through differentiation by means of innovative products, • development and construction of products that ensure fast and flexible fabrication, • development of ecologically friendly products and processes, • development of products with a low susceptibility to failure, • shortening of research and development time to allow a timely response to shifts in the market in the form of new technologies and products, • research in the field of advanced technology to serve markets with high expansion rates.
Production	• reduction of changeover activities, • shorter changeover times, • reduction of volume of stocks and • reduction of defective goods.	• higher flexibility in the production process, • reduction of throughput time, • fabrication of high-quality products and • fabrication and use of ecologically friendly products and production processes.

4 Description of in-company standards

In this chapter we take a detailed look at different company standards. Following a general description there will be statements about the costs incurred and benefits to be expected from the respective standardisation instrument. We will also evaluate the effects of the company standards on different competitive strategies and assess the influence of company, product and market-specific factors on the beneficial effects of using the company standards.

4.1 Class lists of subject characteristics

A class list of subject characteristics is a special form of describing individual components and is part of the classification of an item number system. The scope of application and the design of a class list of subject characteristics are described in a German standard, DIN 4000.

Class lists of subject characteristics are used to describe objects by their main characteristics. This requires making a simple sketch (an outline drawing) to illustrate the features. Generally such features are subject characteristics, relational characteristics, applicability, and physical characteristics that can be expressed in either numbers or letters. The letters from the sketch are listed in a table which contains the values and appropriate designations, measuring units, and further descriptions, if required.

The development or creation of a class list of subject characteristics is done in seven stages:

- **Determine the subject group:**
  The object to be described must be assigned to a subject group.
- **Screen the documents:**
  In this step, all company documents describing the object must be collected and screened..
- **Determine the characteristics:**
  A ranking must now be made of the characteristics, in accordance with their significance. The most important characteristics are included in the class list of subject characteristics, according to the company's specifications.
- **Assign code letters to the characteristics:**
  Code letters support making an association between the feature designations and the outline drawing. In theory, code letters can be specified for each class list of subject characteristics, and they can take any form. The German industrial standard DIN 4000, Part I, Section 5.5 requires that:
  "in different class lists of subject characteristics within the same part of the DIN 4000 series . . . identical feature designations shall be listed under identical feature codes[48]."

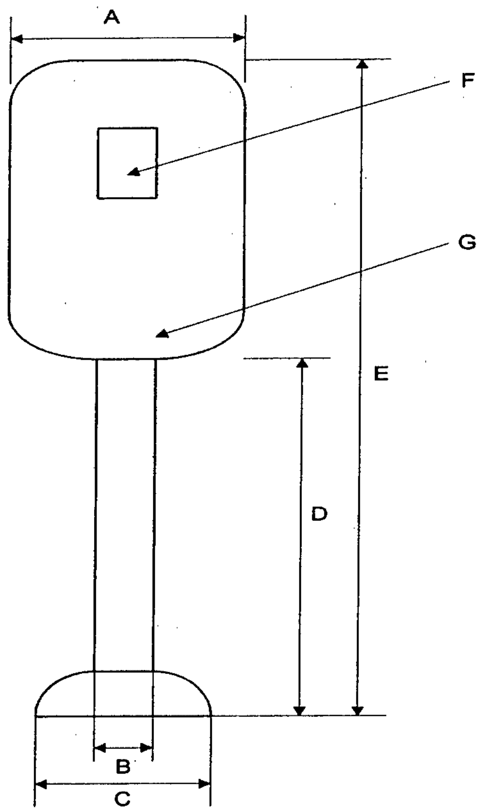
[48] Cited from Gößner (1993), p. 39.

- **Prepare the comments:**
  Only absolutely essential comments should be included.

- **Prepare the sketch:**
  The sketch should show the features included in the class list of subject characteristics to the greatest extent possible.

- **Complete the class list of subject characteristics.**

The above explanation is illustrated below in the diagram of a mixer and the associated class list of subject characteristics.



Class list of subject characteristics **Mixer**					
Subject characteristics	Code	A	B	C	D
	Meaning	Diameter	Diameter	Diameter	Length
Measuring units (letters)		mm	mm	mm	mm
PAC		50	25	60	180
Subject characteristics	Code	E	F	G	
	Meaning	Length	Color	Color	
Measuring units (letters)		mm	RAL	RAL	
PAC		350	1576	4568	

Figure 12: Class list of subject characteristics for a mixer

Before a class list of subject characteristics can be introduced it is necessary to make an exact study of the vocabulary that is used in the company. To ensure a standardised description of components, the vocabulary must be defined before it is used.

To prepare a class list of subject characteristics it is also necessary to have suitable computer programs available that support the use of this approach, and from this arise the necessity of training the staff who will work with these lists in the future. The conditions that must be met before introducing the class lists of subject characteristics are limited to the efforts involved in defining the vocabulary to be used in the future, the provision of suitable computer programs, and the staff training.

The cost savings that are realised in the design are due to the higher re-use quota for already used parts. This makes it unnecessary, for example, to spend time and effort on new designs. There is also a reduced workload in the work planning, since existing drawings and plans can be used and large manufacturing batches permit the use of more efficient production methods. This will generally slow down the increase in the number of parts in the company, and this is a relief for all divisions concerned. However, the disadvantage is the greater amount of time that is required to prepare class lists of subject characteristics.

The costs associated with the introduction of class lists of subject characteristics can be subsumed under the following headings:

- **Programming costs**
  (development or purchase of new computer programs to support the preparation of class lists of subject characteristics);
- **Wages and other personnel costs**
  (possibly including the cost of training courses);
- **Evaluation costs**
  (the valid vocabulary must be defined within the company or by external consultants).

The time required to evaluate the vocabulary strongly depends on the products manufactured by the company. If the number of products and their complexity are low it may be possible to start using class lists of subject characteristics within a short period of time. If there is a great variety of parts and a higher complexity, the time required to start using class lists of subject characteristics may be longer.

4.1.1 Effects of class lists of subject characteristics on company processes and competitive strategies

The introduction of class lists of subject characteristics in a company helps to reduce the reaction time required to manufacture a product. Such a reduction is needed because market requirements are changing ever more rapidly. However, to actually realise such time savings it is not sufficient to merely introduce class lists of subject characteristics as a company tool;

rather, it is also necessary to simultaneously reduce computer access times and to optimise access rights and options. If these requirements are met, the effective use of class lists of subject characteristics can set free considerable cost cutting potentials in a company.

Generally, cost cutting potentials exist in the following company divisions:

- design,
- materials management,
- purchasing,
- production,
- administration.

About 70 percent of the later manufacturing and materials costs are determined in the design phase[49]. Class lists of subject characteristics support the search for repeat and identical parts and permit concerted searches for standard parts that have the properties which are required in individual cases. This can reduce, to a tolerable level, the costs of time-consuming and cost-intensive new designs that require new drawings and production plans. The increase in batch quantities that is associated with this will lead to further cost reductions in the production. A greater use of standard parts will offer diverse advantages in purchasing. In addition to the possibility of being able to rely on a greater number of suppliers, the decisive argument for the use of standard parts is that there are major price differences between design parts and standard parts[50].

The use of individual class lists of subject characteristics will therefore become the basis for preferred sizes that permit rationalisations in the design and in the production planning.

In the medium to longer term, the use of class lists of subject characteristics results in cost savings. A quality increase can also be achieved, because the already designed parts will be technically sound, since they have already been produced and thus there is some experience available with regard to their functionality.

It has been demonstrated that the most pronounced effects on existing competitive strategies are on cost leadership. Due to the re-use of already existing and proven parts it is possible to achieve a high quality of the product, which in turn will support the competitive strategy of differentiation. However, care should be taken to avoid that the use of standard parts results in technologically inferior products, because this would mean that the cost savings have to be "paid for" with an excessive loss of differentiation.

[49] See Bertram (1999), p. 19.
[50] An example of cost reduction with a greater use of standard parts is described in section 5.4.

4.1.2 The influence of product, company and market related factors on the beneficial effects of using class lists of subject characteristics

The possibilities of using company standards – and the later positive effects of using them – are determined by a number of factors. These factors can arise either within the company or they can be of external origin. The internal factors are primarily the result of the respective company-specific structures, or they are due to features of the product; external factors are mainly determined by market conditions and customer preferences.

In order to be able to assess the effects of company standards as accurately as possible, this paper will focus on those factors that exert a significant influence on the effects of company standards. The influence of these factors will be discussed for each individual standard.

Product-specific factors

The benefits from the use of class lists of subject characteristics for the engineering division increase with the technical complexity of the products. The degree of complexity determines the required design effort; it is therefore an important criterion when introducing class lists of subject characteristics. Thus, the benefit of using class lists of subject characteristics is much greater for an engine manufacturer than it is for a manufacturer of cigarette lighters.

Company-specific factors

The greatest potential for sustained cost reductions through the use of class lists of subject characteristics is found in the design division, in materiel management, and in production. The share of these three divisions in the value-added process generally increases with the vertical production depth, which is regarded as a general criterion for the utility of using the class list of subject characteristics as a means of achieving cost reductions. In addition, the application spectrum of class lists of subject characteristics is determined by the similarity of functional characteristics in the production program, since this determines the possibilities of using identical and repeat parts. Reductions in the parts spectrum lead to economies of scale in the purchase of parts and may result in lower purchasing prices. A greater use of standard parts also benefits measures to reduce the supply risk, as this makes it possible to fall back on a greater number of suppliers, which supports the multiple sourcing strategy.

Market-specific factors

The directed use of class lists of subject characteristics in the search for repeat, identical and standard parts reduces the time required for the realisation of a product. This fact becomes even more significant as market conditions and particularly customer preferences become more dynamic. The use of technically proven parts and assembly groups also ensures a high level of product stability and will satisfy the needs of customers who demand high quality.

A greater use of standard parts not only has cost-reducing effects; it also supports the strategy of differentiation. Standard parts are much more easily available than newly designed parts,

due to the large number of potential suppliers. Thus, the maintenance costs of commercial aircraft, for example, are reduced, and a greater flexibility is achieved for the maintenance, which increases the product's utility for the operator. However, it is absolutely essential to make sure that the use of standard parts will not result in technologically inferior products, since this would mean that the cost savings that are thus achieved have to be "paid for" with an excessive loss of differentiation.

These findings are reflected in new instructions for the design engineers at EADS Airbus Company. If a design engineer at EADS Airbus wants to use a design part, he must first submit a request to the standardisation division. On the basis of the technical data of the design part, the standardisation division will check whether a standard part is available that could be used instead of the design part. This process is usually completed within 24 hours.

A greater use of standard parts brings a considerable potential for cost reductions, but so far this has been recognised and implemented by only a few companies. This impression was confirmed by the results of an empirical survey conducted by the Chair for Standardisation and Machine Design in the Department of Mechanical Engineering. In that survey many companies said that the price difference between standard parts and design parts is too small. Further studies are therefore required on this topic at additional companies before accurate general statements can be made on the strategic benefits from the use of standard parts.

4.2 Feature lexicon

A further development of the class list of subject characteristics described above is the so-called "feature lexicon". This takes into account not only the inventory of information that is contained in the class lists of subject characteristics, but also the substantive structure of each single item of information.

The German Standards Institution (DIN) has initiated a standardisation program with the aim of preparing such a feature lexicon. The class lists of subject characteristics are prepared with the aim of standardisation, based on the formalised structure of the feature lexicon.

The primary function of the feature lexicon is to establish a uniform classification system and to define a common platform for the characteristics. In concrete terms, the goal is to achieve standardised descriptions in the following areas in which standardisations are desirable:

- Classification of products and processes according to reference hierarchies, and the description of products and processes on the basis of their features;
- Establishment of a standard reference hierarchy and the required rules;
- Definition of the possible feature variables;
- Description of the features (in terms of structure, substance, and rules).

The executive body of the German Standards Institution (DIN) has established the following requirements that a feature lexicon should satisfy. A feature lexicon should

- provide a standard basis for intra-company and inter-company information exchanges;
- include both product features and process characteristics;
- integrate different areas such as machine design, electronics, quality control, and services;
- support different life-cycle phases and different views of a product;
- include an orderly change system that permits tracking products in their different phases;
- provide support in several languages;
- minimise redundancies;
- permit comparisons of products and processes; and
- support searches involving several subject groups[51].

To this date, the only institution that has established any requirements for the feature lexicon that is to be developed is the German Standards Institution (DIN).

An assessment of whether a feature lexicon should be introduced into a company cannot be based on experience, because to this date there has not yet been a case where an appropriate and fully developed feature lexicon has been prepared. However, we assume that a kind of "reference publication" is now being developed which companies will be able to purchase from the German Standards Institution. This comprehensive publication is being adapted to the special requirements of companies. The demands that will be placed on companies may thus possibly be limited to training courses for personnel that will use the feature lexicon.

At this time it is not yet possible to specify exactly what advantages may be gained from the use of a feature lexicon. If such a feature lexicon satisfies all the specified requirements, the vocabulary of all class lists of subject characteristics will be standardised. This would reduce friction losses that result from differences in designations. Naturally this applies to different companies, as well, such as when all suppliers and customers use the same designations. We can assume that as a result there will be a reduction in the variety of parts and in processing time (e.g., class lists of subject characteristics can be prepared more quickly).

However, the use of a feature lexicon can have disadvantageous effects for a company if the designations specified in the lexicon do not fully describe the characteristics of the products. This would be the case if the company manufactures "niche products" that were not explicitly considered when the feature lexicon was prepared. Such fuzzy designations could result in friction losses.

[51] Cf. Lederer (1998), p. 15.

The costs associated with a feature lexicon can be broken down as follows:

- Procurement costs:
  The feature lexicon must be purchased from the German Standards Institution (DIN).
- Personnel costs:
  The staff who will work with the lexicon has to be trained in its use. If the training is conducted by external experts, their consultation fees must be taken into consideration.
- Data processing and maintenance costs:
  The benefits of using a feature lexicon can be realised in full only if all data are converted to the feature lexicon's vocabulary. Since it would be impracticable to wait until all the old class lists of subject characteristics have disappeared as a result of their obsolescence, they must be converted to the new vocabulary.

In the short term the preparation of class lists of subject characteristics will cost more time, because the staff will first have to learn how to use the feature lexicon. Conversion to the new vocabulary during the creation of the class lists of subject characteristics will not take much time. The standards must be purchased, and for most of the staff it will suffice if they receive a short introduction to the topic.

The medium-term and long-term advantages connected with the introduction of the feature lexicon will depend on the company's business environment. If all suppliers and customers use the lexicon, considerable benefits can be expected for the information flow between the various companies. If this is not the case, the benefits will be limited mostly to the divisions of the company. These benefits include a reduction in the number of parts and an improved communication between the various divisions. There will be risks only if the feature lexicon cannot be applied to the company's range of products, or if this can be done only to a limited extent. In this case the terms that are used will be too fuzzy, which in turn could result in a lower re-use rate for the existing parts.

The effects on competitive strategies are identical with those for the class lists of subject characteristics. The introduction of a feature lexicon has direct and positive effects on the cost leadership and indirect effects on differentiation, since the feature lexicon will "only" permit a better use of the class lists of subject characteristics.

4.3 Numbering systems

Numbering systems are classification systems that are used to support the management of and access to technical information, which is an essential company resource. This makes it clear that a mere introduction of such a system (or the standardisation of the numbering system, if such a system already exists) will not suffice. Rather, it is also necessary to have an efficient data processing system available, or it will be necessary to have such a system installed.

The information that is relevant for a numbering system exists in the form of drawings, lists of parts, catalogues, guidelines, and company standards. Such information is heterogeneous as far as its substance and form are concerned.

Individual documents must be unambiguously identified, so that they can be distinguished from other company documents, and to be able to access them individually.

The information existing in the form of documents is subject to a classification process that depends on the type of information to be classified, the desired features, and the user group. These requirements form the basis for the objectives that a numbering system must satisfy. Thus the information is

- designated as a part of the company;
- identified to distinguish it from other information, and to make it individually accessible;
- presented through a classification system, such that it can be ordered into operable classes and presented in these classes.

In this paper, a classification system is understood to be the structured presentation of classes and of the conceptual relations between them. Further, a class is the summary of those terms that have at least one identical feature. To meet these requirements, two different numbering systems have been developed, not taking into consideration any of the special forms.

1. Classifying part of the number:
   This part supports the substantive description of the object concerned. The classifying part can be a class designation of a numbering system. Objects of the same class have the same classifying part of the number.

2. Identifying part of the number:
   This part of the number helps in accessing the object individually and unambiguously. The identification of objects makes it possible to make a formal distinction between the various objects in a company. As a rule, identification numbers are pure serial numbers[52].

Let us take a look, for example, at a Bundeswehr service number, e.g. 030771 H 21513, which consists of two parts: 030771 H (the classifying part) and 21513 (the identifying part).

This numbering system takes the form of a combination number, because the identifying part of the number is dependent on the classifying part of the number, and without the classifying part of the number the identifying part of the number has no significance. In such a system, the identifying part of the number can and will occur repeatedly, i.e. in each class the count will start with zero. To identify or to search for a part, the entire number is required.

[52] See Hesser (1998).

In a parallel numbering system, by contrast, only the identifying part of the number is needed for this purpose. In practice, the parallel numbering system has prevailed because it is easier to handle in computers (from the point of view of data processing), due to the relevant length of the number.

In a combination numbering system, the entire number must be considered, but in a parallel numbering system, only the identifying part of the number must be taken into consideration. Moreover, an identifying number can be assigned automatically, with the help of a computer, by a central agency of the company for all the other divisions of the company.

Creating the identifying part of a number in a numbering system does not require much work. We must know the number of digits (e.g. six) and the starting point (e.g. 000123). From this point on the numbers are increased consecutively. To create the classifying part of a number it is first necessary to define the structure for the classification. For this purpose we can make a distinction between mono-hierarchical and poly-hierarchical structures. Mono-hierarchical structures are the more common ones. In such a structure, each term has exactly one generic term under which it is subsumed, but in a poly-hierarchical structure this will not necessarily be the case.

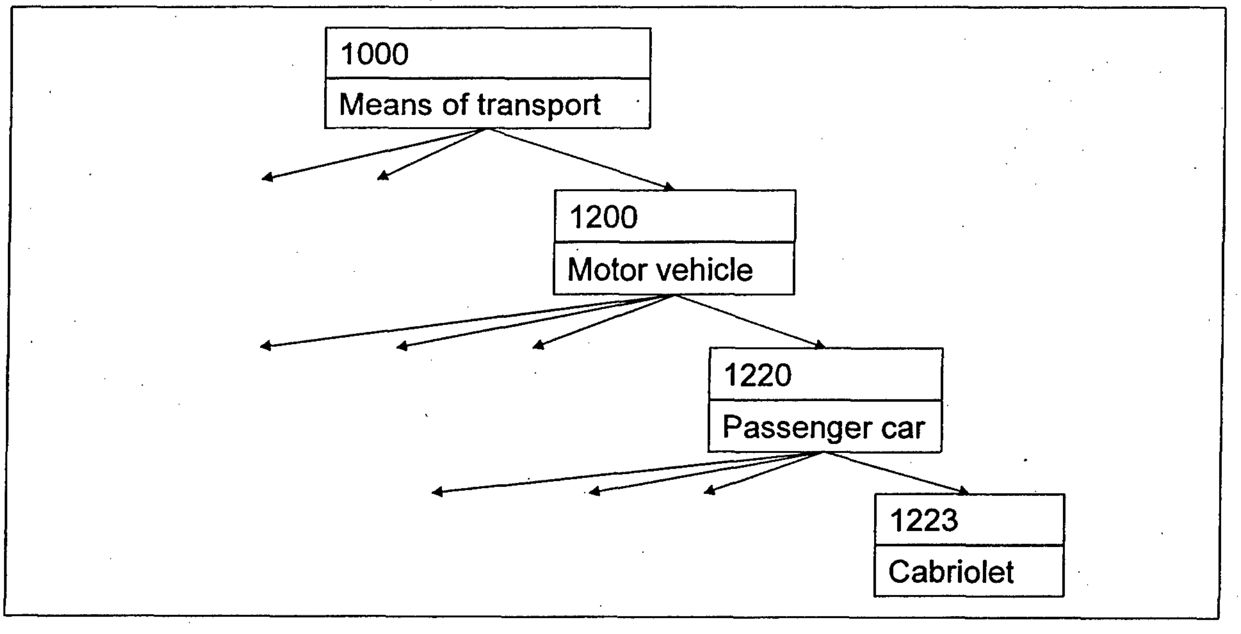


Figure 13: Example of a mono-hierarchical structure

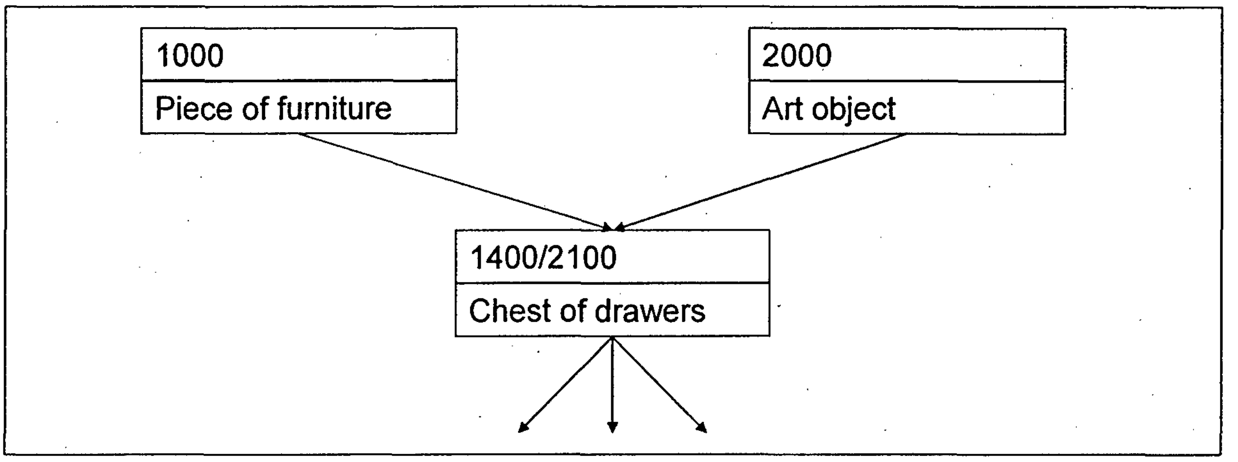


Figure 14: Example of a poly-hierarchical structure

"The structures of classification systems are mostly either decimal or decadic. In a decimal structure, hierarchies are presented in the form of a tree diagram. The individual digits of a number are hierarchically dependent on the preceding digit. For each class it is possible to define ten subclasses, using the numbers 0 to 9[53]."

In such a structure, the complete number must be considered to gain the desired information, as compared to the combination numbering system. Also, such a structure can be expanded almost indefinitely, just by adding numbers. In the decadic structure, on the other hand, this advantage does not exist, compared to the combination numbering system.

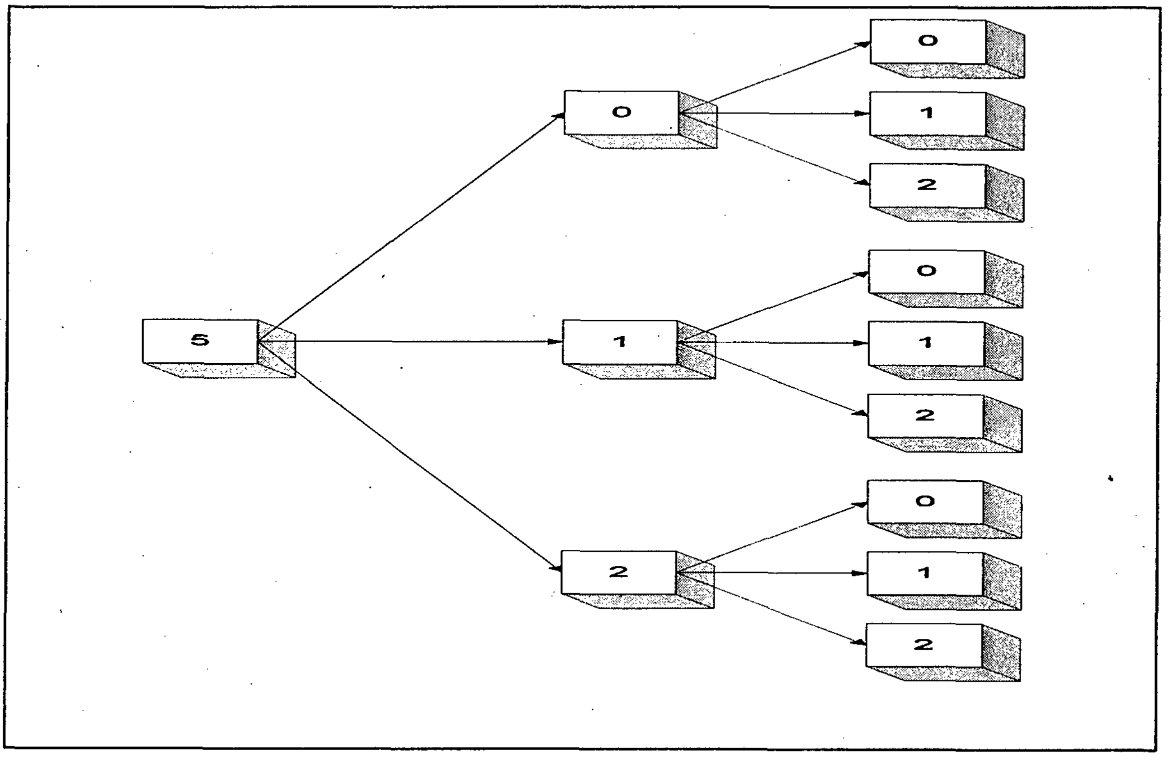


Figure 15: Decimal structure of a number

[53] Cf. Hesser (1998), p. 4.

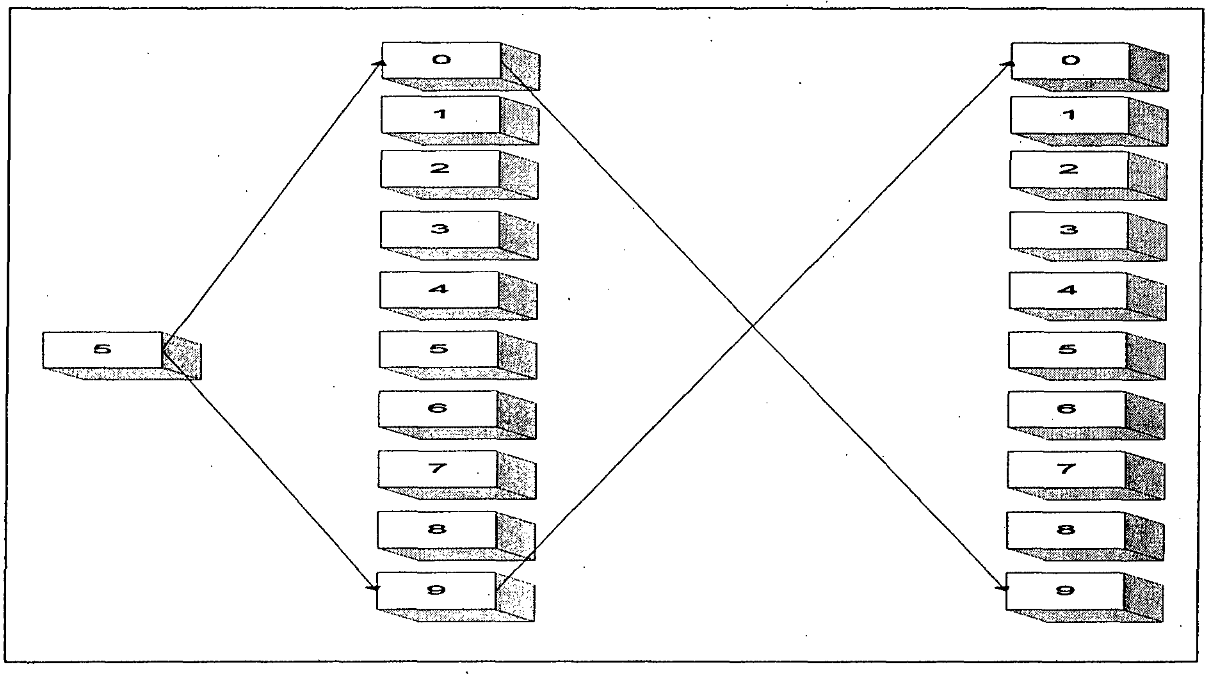


Figure 16: Decadic structure of a number

The benefit from a decadic structure is that information can be gained from each digit of the number. Each digit can be an encryption for one characteristic of the object. If a five-digit decadic numbering system is used, we can describe up to five features of an object, such as material, colour, etc.; however, for each feature there will be no more than ten values available.

The disadvantages of using a decadic structure are these two essential points: First, the overall number is considerably longer than a comparable number with a decimal structure would be. Secondly, the number is not suitable for expansion, because in this structure a maximum of ten values can be expressed for any particular characteristic.

In the planning for such a structure, this limitation makes a very careful and highly prescient approach necessary. It requires making prognoses on the future development of the company so that empty spaces can be left in the numbers for activities that are not yet even current in the company. The structure of the numbering system that will actually be implemented in a company will therefore depend on the business environment and the size of the company.

The introduction of a numbering system requires careful planning. In this regard it is just not enough to make a sufficient number of computers and storage capacity available. Rather, the following issues must be clarified, so that in the long run the numbering system can meet the following company-specific requirements:

- How large is the number of technical objects in the company after a period of X years?
- How will the characteristic features of the objects develop?
- How many objects will be included in each feature group?
- What changes can affect the applicability of the numbers?
- How will information requirements change (types of required features)?

To clarify these issues it is necessary to have a staff team or a person in charge that has access to all the required information. Such a preparation phase is necessary so that the introduction of a numbering system will have a positive effect on the company objectives.

One of the significant benefits of introducing such a numbering system is that in the design work the proportion of original drawings can be increased to up to 70 percent[54]. In addition, the installation of a well-functioning and sufficiently extensive numbering system can be the basis for a comprehensive information system for the entire company.

The introduction of such a system will have adverse effects only if the system is insufficiently implemented. In such a case there may be no effect from a reduction in the number of parts, since only a small percent of the already existing components and drawings can be re-used.

A special problem arises when the capacities of the numbering system are too small. If the system does not have sufficient capacities in some areas to store the relevant information, this will have the effect that a completely new system will have to be built up.

The costs of installing such a system can be subsumed in the following two main categories:

- Personnel costs:
  These include the labour costs of the participating agencies which have been charged with clarifying the issues mentioned above. If these tasks are contracted out, the costs for the external consultants will have to be taken into consideration. If this is a complex system it will also be necessary to train the staff concerned with its application.
- Programming costs:
  When a comprehensive numbering system is introduced, all programs that are affected by it will have to be adapted.

Since we can assume that all companies already have a numbering system, the costs that may result from the necessity of having to purchase new hardware can be assessed as rather low.

4.3.1 Effects of numbering systems on company processes and competitive strategies

The short-term chances and risks involved in the installation of a new system are negligible, because merely clarifying the issues and making the relevant prognosis will take longer than

[54] Cf. Hesser (1998), p. 8.

the time that is required for this. In the long term it may be possible to effect a reduction in the variety of parts. This will make it possible to reduce the amount of capital tied up in the material storage by about 20 percent, and the capital that is tied up in the supply storage can be reduced by about 50 percent. The cost of determining an item number is estimated to be about € 500 to € 1,500 on the average, which explains the capital savings to be gained in the different types of storage. Risks will only arise if a faulty system is installed[55].

The introduction of a suitable numbering system will lead to cost reductions in the design and materiel management, and will thus benefit the competitive strategy of cost leadership. Thus, a suitable numbering system will reduce the reaction time for responding to customer requests in the spare parts service, and will generally improve the customer services. This supports the competitive strategy of differentiation.

4.3.2 The influence of product, company and market related factors on the beneficial effects of using numbering systems

As a rule, nearly all companies have numbering systems that are capable of unambiguously identifying raw materials, production supplies, technical drawings, item lists, etc. Thus the question is not whether a numbering system should be installed or not; rather, the question is what conceptual design will best satisfy the requirements. The particular nature of product, company and market factors can thus be an indicator of the impact that a numbering system will have on the value-added process.

Product-specific factors

Numbering systems are used to search for information. The quantity of the material and the immaterial goods that are required for manufacturing a product is thus an important factor.

Company-specific factors

The productivity of highly automated manufacturing processes substantially depends on whether the supply of raw materials and manufacturing supplies is assured. The growing integration of electronic data processing into the production process is evident in numerous concepts of computer-integrated manufacturing processes[56]. The result is that the processes are becoming more and more efficient. However, if there are any failures or disturbances in these processes, this can have a highly negative effect on the value-added process. If the parts supply, for example, is conducted according to the just-in-sequence principle, a bottleneck in the supply process can lead to a standstill of the entire production process. In such cases, the faulty numbering of parts can have severe consequences for the productivity.

[55] Cf. Hesser (1998), p. 8.
[56] An overview of CIM information systems is contained, for example, in Scheer (1990), p. 2.

Market-specific factors

In the evaluation of a numbering system, the market-specific factors are mainly the result of the relations and information flows between the company and its upstream and downstream manufacturers and between its divisions (production locations). An expansion of production capacities by buying other companies in the same sector may prove exceedingly problematic if different numbering systems are used. In this case the hoped-for synergies and economies of scale frequently do not meet management expectations. The necessary standardisation of the numbering systems may involve huge costs. If different numbering systems are used, the relations to suppliers and customers are also problematic. The stronger the business structure is influenced by these factors, the higher will be the demands on the structure of a numbering system and its management.

4.4 Size range systems

An important method of rationalisation in development, design and production is the use of size range systems. A major advantage of using size range systems is that the design work is reduced because it has to be done only once for many applications. Through duplication in fixed batch sizes it is possible to manufacture more economically.

The term "size range" is used to refer to components, assembly groups and machines that

- perform similar tasks using the same technical solution (and that have identical characteristics, as far as possible);
- cover a broad range of applications in the appropriate size variation; and
- are manufactured in the same way, as much as possible, in all size gradations, that is, they perform the same functions with the same technologies in all different sizes.

Size ranges should be developed in a well-directed and efficient manner in order to ensure that the functions are performed completely across the entire size range, and to tie up as little development capacity as possible. The technical construct that is developed first is called the "basic design" or "mother design", and the size range elements derived from it are "sequential designs" or "main configurations". The sequential designs may be either larger or smaller in size than the basic design[57].

An important design principle in the development of a size range is the so-called "similarity law". We speak of "similarity" when the basic design and the sequential designs have at least one physical feature where the relationship is constant, i.e. the proportions are invariable.

If this is initially limited to basic features such as length, time, force, electricity, temperature, or light intensity, we can define basic similarities. A geometric similarity exists, for example, when the relations of the respective lengths to each other in the sequential designs of the size

[57] See Kleber (1994).

range correspond to those in the basic design. The principle of the "pantograph design" will thus be applied only rarely because such a design (in which there is merely a pure geometric enlargement) is permissible only when additional similarity conditions are fulfilled.

If the relations are constant between more than one of the basic features, we have a special similarity that permits us to make a special statement. For example, if there is a concurrent invariance of length and time, this is called a "kinematic similarity"[58]. We can also define static, dynamic, and thermal similarities, and the dynamic and thermal similarities can be defined even further by means of indicators (e.g. Cauchy number).

The most important similarity relations for a mechanical design can be presented as follows:

[58] Cf. Pahl and Beitz (1997), p. 576.

	Similarity	Basic Characteristic	Invariant	
Basic Similarity	geometric temporal force electrical temperature photometric	Length Time Force Electrical quantity Temperature Light intensity	$\varpi_L = L_1 / L_2$ $\varpi_t = t_1 / t_2$ $\varpi_F = F_1 / F_2$ $\varpi_Q = Q_1 / Q_2$ $\varpi_\theta = \theta_1 / \theta_2$ $\varpi_B = B_1 / B_2$	
	Similarity	**Invariant**	**Indicator**	**Interpretation**
Special Similarity	kinematic	ϖ_L, ϖ_t		
	static	ϖ_L, ϖ_F		
	dynamic	$\varpi_L, \varpi_t, \varpi_F$	Newton Hooke Cauchy Froude NN Reynolds	Inertia Elasticity Inertia / elasticity Inertia / gravity Elasticity / gravity Inertia / friction in fluids and gases
	thermal	ϖ_L, ϖ_θ $\varpi_L, \varpi_\theta, \varpi_t$	Biot	Supplied or dissipated heat quantity Stored heat quantity

Figure 17: Similarity relations

To define the size gradation between similar components, a decimal-geometric sequence of normal numbers may be used. A decimal-geometric sequence is established by multiplication with a constant factor ϖ and stretching it out between the decades. The constant factor ϖ is the gradation increment of the sequence and is a result of

$$\varpi = \sqrt[n]{\frac{a_n}{a_0}} = \sqrt[n]{10}$$

where n is the number of increments within a decade. For ten increments, for example, the sequence would have a gradation increment of $\varpi = \sqrt[10]{10} = 1.25$; this is called "R 10"[59].

Figure 18 provides an overview of the principal values of normal number sequences.

The exact gradation of a size range not only depends on a fixed sequence of normal numbers but also on customer preferences and market requirements. This means that for an optimal size gradation it could be appropriate not to use constant gradation increments to divide the size range into the required sizes of the product series. Rather, from a technical and economic point of view it may frequently be more advantageous to structure the size range according to other or different size increments, and/or to leave gaps.

[59] Cf. Pahl and Beitz (1997), p. 580.

Principal Values of Basic Sequences			
R 5	**R 10**	**R 20**	**R 40**
1.00	1.00	1.00	1.00
			1.06
		1.12	1.12
			1.18
	1.25	1.25	1.25
			1.32
		1.40	1.40
			1.50
1.60	1.60	1.60	1.60
			1.70
		1.80	1.80
			1.90
	2.00	2.00	2.00
			2.12
		2.24	2.24
			2.36
2.50	2.50	2.50	2.50
			2.65
		2.80	2.80
			3.00
	3.15	3.15	3.15
			3.35
		3.55	3.55
			3.75
4.00	4.00	4.00	4.00
			4.25
		4.50	4.50
			4.75
	5.00	5.00	5.00
			5.30
		5.60	5.60
			6.00
6.30	6.30	6.30	6.30
			6.70
		7.10	7.10
			7.50
	8.00	8.00	8.00
			8.50

Figure 18: Excerpt from DIN 323 (principal values of normal numbers)

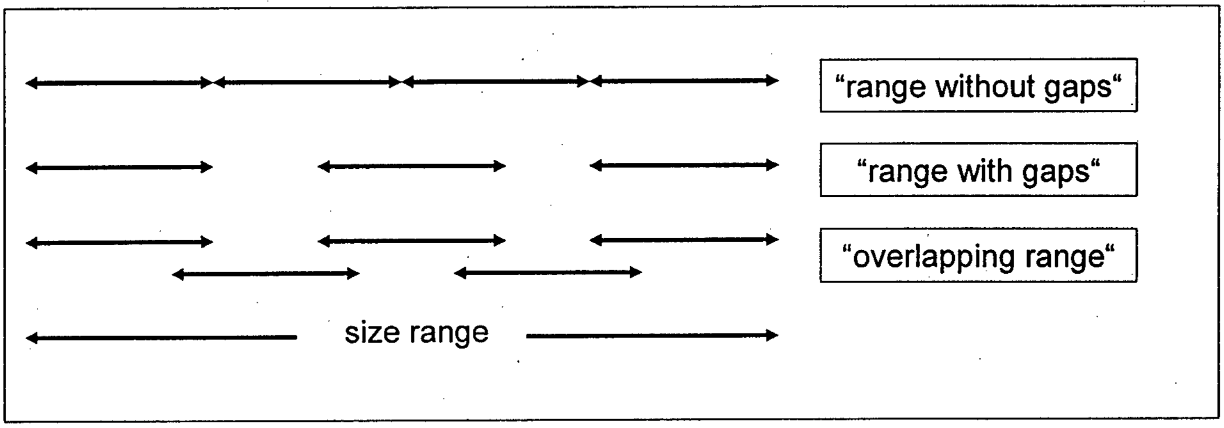


Figure 19: Options for establishing or choosing size ranges[60]

If products of different sizes are to be manufactured, it may be useful to develop and design size range systems on the basis of normal number sequences. The design of these products can then be based on similarity laws. For this it is necessary to examine which laws can be applied and whether the application of the rules derived from them is technically feasible.

It is also necessary to determine the gradation increment. Size ranges can be graded on the basis of different procedures. These can be based on purely technical considerations or on economic considerations. Moreover, a study must be made of whether the customers will accept the gradation in the size range, that is, whether the customers need these products in these sizes. In this context it is also necessary to decide whether a single sequence is to be used for the entire size range, and whether the size range should be "without gaps", "with gaps", or "overlapping"[61].

4.4.1 Effects of size range systems on company processes and competitive strategies

The introduction of size range systems in a company simplifies the development of products that belong to the same range, since is unnecessary to make individual designs for each size. This reduces the number of designs in the company, because the company no longer needs to manufacture for each specific customer preference. Another advantage is that it is possible to use the same materials, which reduces procurement costs and permits using the same tools.

Problems arise when the products in a size range no longer conform to customer preferences. This can occur if the customers have special wishes or demand special functions that cannot be integrated into the size range. In such a case the development of an individual design may again be necessary. Moreover, the design of individual size gradations may not be the best approach because this must be done on the basis of the similarity laws. Therefore, individual product segments may become oversized compared to individual designs.

[60] Cf. Friedewald (1972).
[61] Cf. Pahl and Beitz (1997), p. 583.

The costs associated with the introduction of a size range system are mainly incurred in the development and design phase, when different sizes must be designed using similarity laws. The expected customer behaviour must be determined during the marketing phase. During the work planning phase there will be a reduced workload, because theoretically the plans can be used for all sizes. This will have positive effects on production, because the workflow will be nearly identical, and this may make it possible to improve the quality of products. By using the same materials as much as possible it will be possible to reduce the number of machines employed and the quantity of cutting materials.

For an assessment of the short-, medium- and long-term chances and risks that are connected with the implementation of such a measure, we choose as our starting point the time when the product is put on the market. Of course, the design of a size range essentially depends on the complexity of the product. Since it is impossible to specify the exact length of time that will be required for this, it will not be taken into consideration in this context.

After a product is launched, the sales volume frequently decreases because it is not always possible to completely satisfy the respective user demands[62]. During this phase there is the risk that too many customers may be lost. In the medium to long term, however, there is the possibility that customers may adapt their requirements to the size range. This may make it possible to establish a basis to which other manufacturers can adapt their products. In the extreme case this can result in a standardisation of the entire market.

The development of size ranges can be a highly effective rationalisation instrument in design and production. The cost reductions are made possible not only by reducing the design effort; it is particularly the larger production batches and the reduced number of components used that permit the company to reduce its costs. The development of size ranges can thus support the competitive strategy of cost leadership.

In general, the design of products based on the size range principle makes it more difficult to differentiate between products, because product characteristics are predetermined by the size variation. However, differentiation may be possible when a customer already uses a product of the size range. The customer will then be informed about the characteristics of the entire size range. This is not possible with a customer-specific design.

4.4.2 The influence of product, company and market related factors on the beneficial effects of using size range systems

Product-specific factors

The benefit of using size ranges is generally highest when the design effort is reduced to a minimum. The cost savings achieved will therefore increase as the number of performance variants increases and as the size gradation becomes more detailed. In this connection it is

also advantageous to have a large number of basic and specific similarities because this will permit further reductions in the design work.

In addition, the benefit from a size range will increase with the degree of complexity, in the sense of the parts installed in an assembly group or component. Assemblies and components developed on the basis of the size range principle are usually characterised by an exceptional stability; they should therefore fulfil a primary function of the product, one whose stability is of great importance to the customer. An example of this is the primary function of propulsion performed by the engines of motor vehicles, ships, and aircraft.

Company-specific factors

From a production engineering point of view, the benefit to be derived from a size range system increases with the automation level in production. While it must be conceded that some types of industrial production process[63] such as shop fabrication and team work in line islands will show high levels of flexibility during production conversion, the productivity in duplicate or continuous production substantially depends on high levels of capacity utilisation and on the rarity of set-up procedures. The standardizing effect that a size range system will have on the requirements of production processes combined with larger production batches will increase the productivity in a highly automated production process. The reduction in the design work will be an advantage, especially when the possibilities of outsourcing in the research and development function are severely limited.

Market-specific factors

Due to the graded performance characteristics of assemblies and components based on the size range principle, there are generally fewer options available for product differentiation. This leads to the danger that these firmly established performance characteristics may not sufficiently satisfy the customer preferences, which will lead to a decline in sales. But the less a customer's purchasing decision is influenced by the performance characteristics in a function of the product, as specified by a size range, the smaller will be the decline in sales.

Considered from this perspective there seems to be relatively little objection, for example, to designing a transmission on the basis of the size range principle. However, the performance and fuel consumption of an engine may be regarded as an important purchasing criterion. If, in a purchasing decision, such important criteria are satisfied by the assembly or component, then these technical functions should be given appropriate consideration when the customers are lumped into homogeneous groups. Thus a limited number of performance variants may make it possible to restrict the decline in demand to a tolerable level. Moreover, a lack of elasticity in purchasing behaviour can be an advantage with respect to the product functions

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[62] Quoted from Kleber (1994), p. 49.

[63] An extensive description of the types of industrial manufacturing process is found in Kern (1990), p. 89; Reichenwald and Mrosek (1990), p. 380; Schneeweiß (1989), p. 10.

established in the size range system, because in these cases, slight deviations will have little influence on purchasing decisions.

4.5 Unit assembly systems

Another method of standardisation is the unit assembly design. According to Hesse, the unit assembly principle in production engineering implies that the products are decomposed into standardised building blocks or components that can be used to construct a certain number of products[64]. This method was developed to help reduce the diversity of parts in companies.

The development of a unit assembly system may be appropriate if the various functions of the product can be performed in one or in several size gradations by combining the appropriate production items and/or assembly groups (functional building blocks).

The following will describe the most important principles of a unit assembly system. Unit assembly systems are produced out of functional and production units which are combined such that they will be either separable or inseparable. Unit assembly systems can usually be disassembled. Generally the units of a unit assembly system are classified according to their size (big and small units), function (equipment element, accessory element, joining element), and importance (priority) within the modular system (elements of equal or preferred status).

To obtain a more exact specification of the elements in a unit assembly system, they can be classified according to their functions. A "pure" unit assembly system only consists of basic, special and auxiliary elements; a so-called "composite system", however, may in addition be supplemented by adapter units as well as by components that are not elements of the system.

A unit assembly system can also be characterised by the degree to which individual elements can be disassembled, which is an indicator for the degree to which the product can be broken down into its elements. This is therefore primarily a production-oriented characterisation.

The sub-functional elements can be exchanged to obtain fully functional variants. Among these we can distinguish between "mandatory variants" (which means that one of these sub-functional elements must always be included in the respective product variant) and "optional variants" (which means that these elements can be used as accessories or equipment units, if required).

Regarding the scope of application and the delimitation of a unit assembly system we can say that a closed system is defined by a so-called "assembly program" in which all of the possible combinations are planned in advance and then combined into a unique system, e.g. a gearbox. In an open system, where it is not yet possible to fully estimate the entire variety of possible combinations (such as in modular furniture), the scope of application is established by the

"configuration plan". Thus, an assembly program is a complete catalogue of all combinations that are possible. A configuration plan, however, is only a sample listing of combinations.

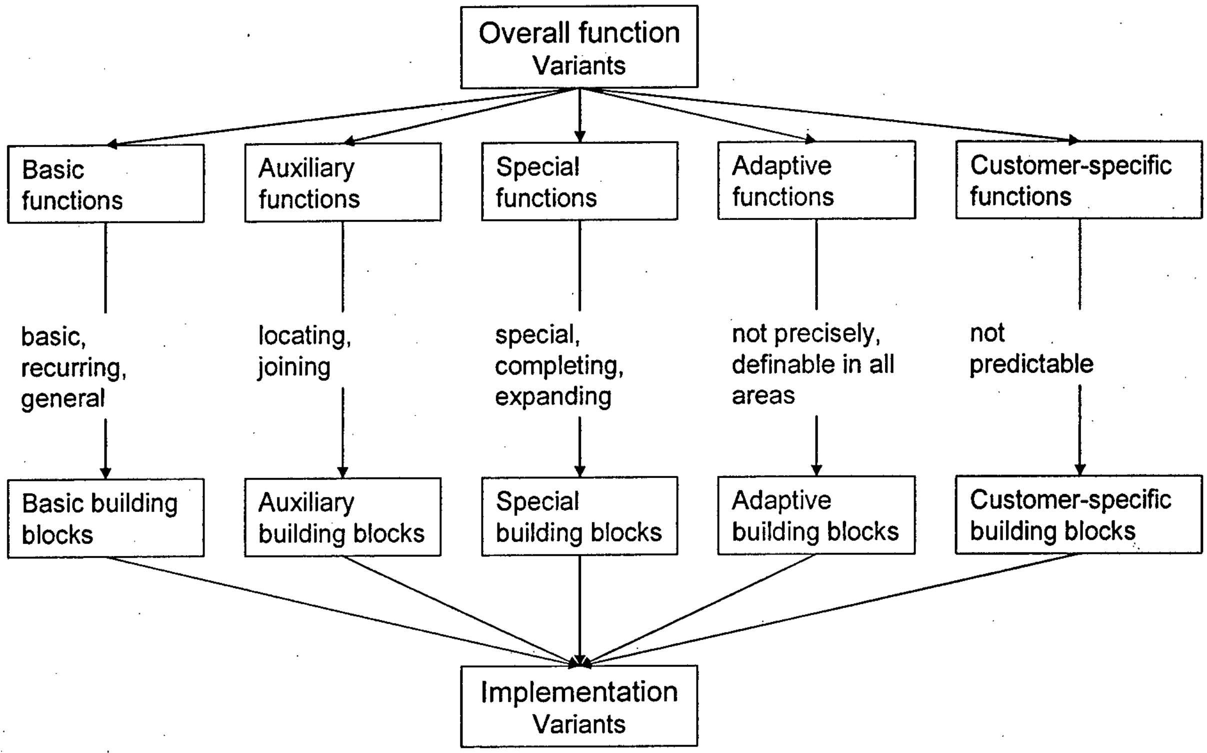

Figure 20: Building blocks in a unit assembly system[65]

The general procedure in developing a unit assembly system consists of the following steps:

- Make a list of the requirements;
- Define the functions and the functional structure (see the classification of building blocks);
- Define the concept (search for principles to solutions for individual functions);
- Choose the concept;
- Prepare the designs to scale;
- Prepare the documentation for production and for filling the orders.

These six points are only a general plan; from case to case it may have to be specified in more detail.

The possibilities of using unit assembly systems are determined in particular by the product range of the company. In general, the benefit from using a unit assembly system increases as the number of identical functional solutions in the various products increases, since this will increase the frequency of the same building blocks being used. If, for example, a company's product range consists of automobiles only, it is possible to identify frequently used building

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[64] See Hesse (1993), p .46.
[65] Cited from Pahl and Beitz (1997), p. 608.

blocks. If, on the other hand, the product range only consists of special items made to order for the machine building industry, it is difficult to develop a practical unit assembly system.

Before a unit assembly system is introduced into a company it will be necessary to check which products can be combined in such a system. The decisive criterion is the purchasing behaviour of the customers. Customer preferences must be included in such considerations because the characteristics of products manufactured for unit assembly systems may partly not be as good as those of comparable single designs. If these customer preferences are not sufficiently taken into consideration when the unit assembly system is to be introduced, the company may develop its products "past the market" and thus weaken its competitiveness.

The advantages and disadvantages of unit assembly systems not only have effects for the manufacturer but also for the user and the customer, which can be of crucial importance for the company's business success.

The advantages for the manufacturer are:

- Simplified pricing;
- Only orders for some additional equipment will make additional design work necessary;
- Simplified work planning and a better production scheduling;
- Standard building blocks can be produced in more advantageous batch sizes, independent of specific orders; this can lead to more cost-effective tooling and production processes;
- Order processing time can be considerably reduced through parallel productions in the unit assembly approach; this reduces the time required to deliver the goods;
- Orders processing with the computer are facilitated.

The user will also have a number of advantages:

- Exchanges and repairs are facilitated;
- Spare parts services are optimised;
- Future functional changes are possible within the spectrum of variants (multi-purpose use);
- Defect potentials are practically eliminated (mature design).

The disadvantages for the manufacturer can be described as follows:

- Compared to single designs there is only a limited possibility of adapting to special customer demands; there is a danger of reduced flexibility and market orientation;
- Assembling the products requires more effort and care;
- Matching surfaces must meet higher standards; tolerances must be lower, because rework is not possible;
- Design work is necessary only at the start; therefore, if the structure of an assembly has been defined, shop drawings are frequently made only after orders have been received; thus the inventory of drawings required for production programs is filled only gradually;
- Product modifications are economically justified only over long periods of time, because the unique development costs are relatively high.

The user also has disadvantages:

- Due to over-sizing that may partly be required, weights and volumes are frequently greater than in products specifically developed for a functional variant; this leads to greater space requirements and greater costs from the construction of foundations;
- Special needs of users are difficult to satisfy;
- Quality requirements are more difficult to meet than in single designs[66].

This long list of advantages and disadvantages makes it clear that a company which is about to decide on whether to introduce a unit assembly system must thoroughly examine to what extent these advantages and disadvantages apply to its own products.

The development of a unit assembly system requires more effort than does the design of a single product. Therefore the development and design of unit assembly products involves higher costs. These are due to the market analyses that are required, not only to determine current demands but also the future demand that is to be met by the unit assembly product.

There is also a cost increase in the design phase, due to testing the unit assembly system[67]. This is contrasted with cost reductions in work planning and production. In work planning, the workflows have to be developed only once for each building block. The same applies to preparing the parts lists and class lists of subject characteristics. In production, the costs are reduced by the increase in batch sizes.[68]

4.5.1 Effects of unit assembly systems on company processes and competitive strategies

In the short term, the introduction of unit assembly systems involves considerable risks that are essentially due to the design costs and to the costs of converting production processes, as required. Also, due to the disadvantages of the unit assembly design, customers may change their procurement decisions to purchase complementary goods from other manufacturers.

In the medium to longer term, the introduction of unit assembly systems has the advantage that the quality of the products will improve. Moreover, the service life of products will be increased, the time required for deliveries will be reduced, and prices will be lowered[69].

The introduction of unit assembly systems can support the competitive strategy of a company in both differentiation and cost leadership. The most pronounced effect is on cost leadership, due to the greater flexibility in production, thus allowing the production of bigger batches, which reduces the setup costs. Differentiation is achieved through improvements in product characteristics, such as a lower susceptibility to breakdowns, easier maintenance and repairs, and improvements in spare parts supply. If the production depth can be reduced at the same

[66] See Pahl and Beitz (1997), p. 621.
[67] See Kleber (1994), p. 40.
[68] Cf. Kleber (1994), Chapter 3.1.2.
[69] Cf. Kleber (1994), Chapter 3.2.

time that the unit assembly system is introduced, this will make it possible for the company to focus on its core competences.

4.5.2 The influence of product, company and market related factors on the beneficial effects of using unit assembly systems

Product-specific factors

The functions of components based on a unit assembly system should be applied in as many products as possible in order to facilitate greater effects of scale in the value-added process. Particularly open systems (which are noted for their relatively high procurement costs) offer the advantage that customers can buy a product with a limited functional spectrum and then, depending on their needs, they can extend the product's functions by successively buying new units.

This effect has induced many furniture manufacturers, for example, to manufacture their products on the basis of the unit assembly system. This lowers the financial entry threshold for consumers and, in the longer term, binds the customers to the company and its products. However, to justify the great design effort that is necessary, the technological progress in the functions concerned should be relatively small.

Company-specific factors

The possibility of manufacturing large batches, independent of any specific orders, increases the productivity in highly automated production processes such as duplicate and continuous production. This advantage grows continuously as the relative share in the manufacturing process increases in the value-added process.

Market-specific factors

If the customers have an exceptionally strong interest in a low susceptibility to breakdowns, uncomplicated maintenance, and short delivery times, the products based on a unit assembly system will be highly competitive. Due to the great variety of combinations and possibilities of open systems, unit assembly systems are particularly suited for the type of customer who does not have standard ideas concerning the future application of the product. Unit assembly systems are also well-suited for customer groups that are not very strong financially, because the functions can then be expanded successively by purchasing additional building blocks.

4.6 Modularisation

In the literature, frequently there is no clear distinction between the terms "modularisation" and "unit assembly system"[70]. Rather, it is often said that a module is just a very complex building block. This view must be rejected, as is shown by the following discussion of the respective interfaces.

In a unit assembly system, the interfaces between units can be such that they are connected permanently. Modules, however, are characterised by clearly defined interfaces between the units. These must be separable from each other. The interfaces between individual modules are aligned with the interface of the basic element[71]. In a unit assembly system, on the other hand, the compatibility of the interfaces between the respective add-on elements is crucial[72].

This difference is also reflected in the relations between the building blocks or modules. In a modular design there should be only a minimum of relations between the individual modules. In their elementary relations (that is, their internal structures), the relations between modules are more pronounced[73].

The objective of modularisation is different from that of a unit assembly system, as is made evident by the following definition: "A special principle for decomposing and structuring a comprehensive overall system is modularisation, which is used to reduce the complexity of the system while taking specific design purposes into consideration[74]."

The complexity of a product can be reduced by reducing the number of the elements and the number and intensity of the relations between these elements[75]. In the unit assembly system, one very important objective is to reduce the variety of parts; in modularisation, an important objective is to reduce the complexity of the system. In view of these divergent objectives it is therefore quite possible that a modular system may use a greater number of parts than a unit assembly system.

Modularisation not only permits displaying the status of the system at any given moment; in addition it is also compatible with the dynamics within the system, since the structure of the modular system offers the advantages that it is flexible and can be modified and expanded. The objective of modularisation therefore is to establish a modular hierarchy focussed on the reliability, flexibility and changeability of the system[76].

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[70] This view is held, for example, by Wüpping. See Wüpping (1993), p. 13.
[71] An exception is "free modularisation", where – similar to the building block system – the compatibility between module interfaces is an important criterion.
[72] Cf. Rapp (1999), p. 52
[73] Cf. Göpfert (1998), p. 141.
[74] Cf. Wohlgemuth-Schöller (1998), p. 12. In this context, Gagsch also speaks of "islands that create complexity". See Gagsch (1980), p. 2157.
[75] Cf. Patzak (1982), p. 23.
[76] Cf. Wohlgemuth-Schöller (1998), p. 12.

4.6.1 Interfaces, forms of modularisation, and the design of modular products

4.6.1.1 Interfaces

Interfaces are a characteristic feature of modularisation. Generally speaking, an interface is the junction between two subsystems[77]. In modularisation, an interface therefore defines the connection between modules. One problem in this respect is that the further development of individual modules must be made possible, that is, the interfaces must be designed such that they will also meet the future requirements. From this experience it follows that interfaces must satisfy numerous requirements:

Technical Requirements:

- Design Requirements:
  Geometric requirements,
  disassembly capabilities,
  similarity of parts.
- Transition requirements:
  Dynamics,
  information transmission,
  capacity.
- Growth requirements:
  Quantitative growth,
  qualitative growth,
  innovative growth.

Economic Requirements:

- Maintenance requirements:
  Dependence on personnel,
  dependence on spare parts,
  dependence on tools and facilities.
- Service-life requirements:
  The service life of the assembly group (or module) must be shorter than, equal to or longer than that of the super-ordinate system.
- Cost requirements:
  Cost reduction and profit maximisation[78].

[77] Cf. Wohlgemuth-Schöller (1998), p. 13.
[78] Cf. Dreger (1982), p. 158.

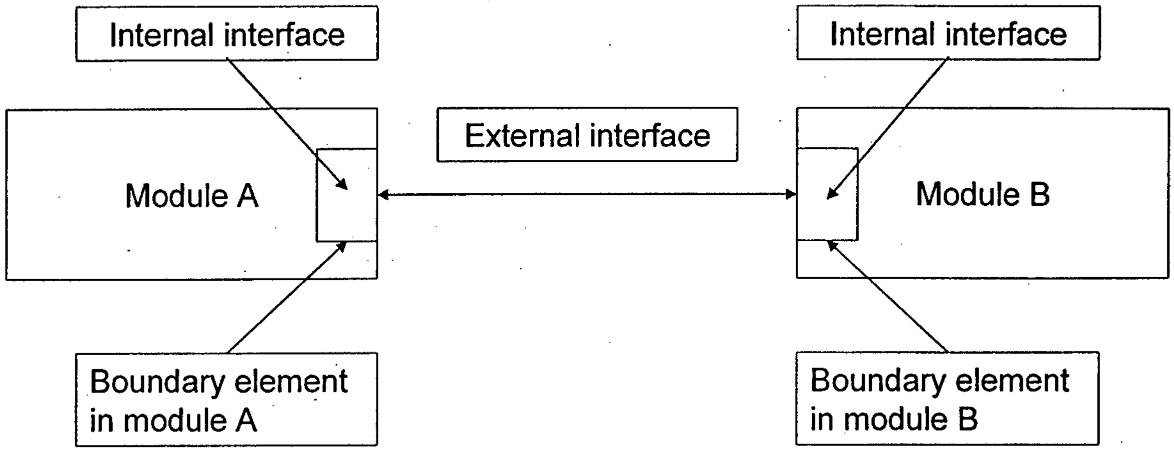

Figure 21: Interfaces and boundary elements[79]

These requirements naturally affect only the internal interfaces and not the external ones. This distinction must be made because only the internal interfaces are realised, that is, they are physically present, and they must therefore be integrated into the respective module.

Dividing a product into sub-functions that are completely separate from each other offers a number of considerable advantages for applications of the modularised product. Due to this feature, modules can be exchanged and replaced without risking the functional efficiency of the overall system. This capability of being exchanged and replaced is particularly important when an advanced version of a component is integrated into the system, or when a variant of the system must be developed[80]. This is another major difference compared to unit assembly systems, where an individual unit cannot be replaced without affecting the functioning of the overall system.

4.6.1.2 Forms of modularisation

In practice there are different forms of modularisation. As is shown in figure 22, we can distinguish between four different forms of modularisation[81]. These forms are the generic, quantitative, individual, and free modularisation. The criterion for delimiting between the forms of modularisation is the product structure that is defined by the modularisation.

In generic modularisation, the product always consists of the same number of standardised modules. Each variant of the module is joined to the basic product with an interface that is specifically designed for this purpose. Because the number of modules is always the same, the customer can only influence the characteristics of individual standardised modules, and thus influence the desired functional characteristics. In generic modularisation it is thus not

[79] Cf. Dreger (1982), p. 155.
[80] Cf. Suhr (1993), p. 71.

possible to reduce or increase the number of product functions by changing the number of modules that are installed. However, this does not apply to a quantitative modularisation, where there is the possibility of employing a variable number of standardised modules.

In individual modularisation there is an even greater degree of structural freedom. This form of modularisation allows assembling the product from a variable number of modules, and the product can either be standardised or customised to the needs of individual users. However, in this type of modularisation, as well, the basic product remains unchanged, since it is the permanent platform for the modules.

The highest degree of freedom with respect to variety and customisation is offered by free modularisation. In this form, standardised and customised modules can be combined freely without the need for a basic product. However, this form of modularisation places very great demands on interface design, since there must be the highest possible degree of compatibility between individual modules in order to permit a sufficient number of combination options.

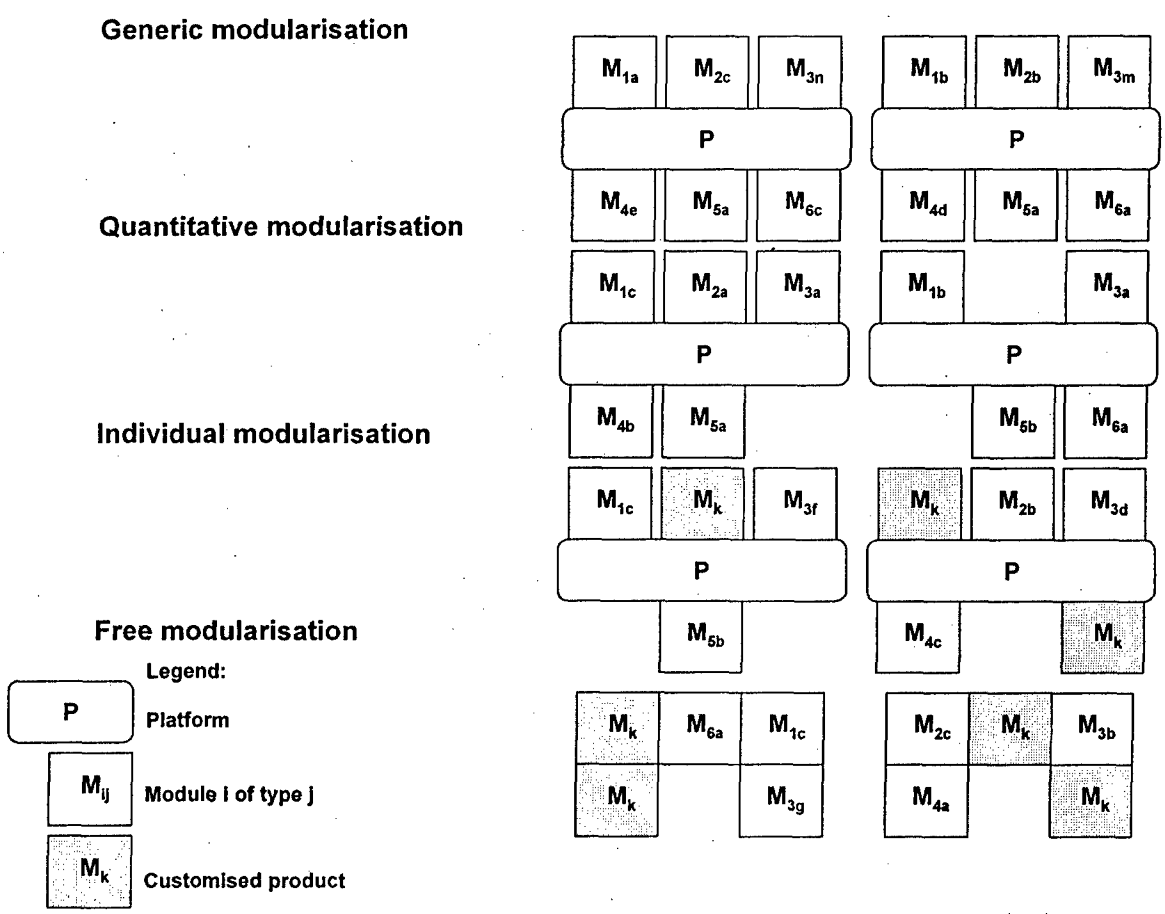

Figure 22: Forms of modularisation[82]

[81] See Piller and Waringer (1999), p. 46.
[82] Based on Piller and Waringer (1999), p. 47.

4.6.1.3 Modularity on different system levels

As we look at the hierarchical structure of a technical system we can normally see an increase in standardisation and a decrease in the specialisation of subsystems. On the lowest system level a product consists of parts that perform basic functions, like screws and cables. This parts level may be called the lowest modularity level, on which many parts are standardised[83]. Frequently these are so-called "off-the-shelf" parts. These parts are standardised and are thus interchangeable; they have simple interfaces; they are offered by many suppliers. Standard parts are usually differentiated according to price and availability; they are offered in catalogues; and they can be purchased in large quantities. As a rule they are therefore procured through global multiple sourcing.

At each higher system level, the combination of basic parts leads to more specific systems. The shape of components and the relations between them are more varied than for basic parts. The interfaces are more complex and less standardised, and modularisation is therefore more demanding.

At the highest subsystem level, components are combined into assembly groups. As a rule these are very product-specific components, that is, they are designed for the product function and can therefore not be used for any other purposes. This means that the interface will also have a high degree of specificity and complexity, and modularisation will therefore require a considerable effort. The highest subsystem level usually has a very specific design, that is, it is tailored to the function of the system, and thus it can hardly be used for any other purpose.

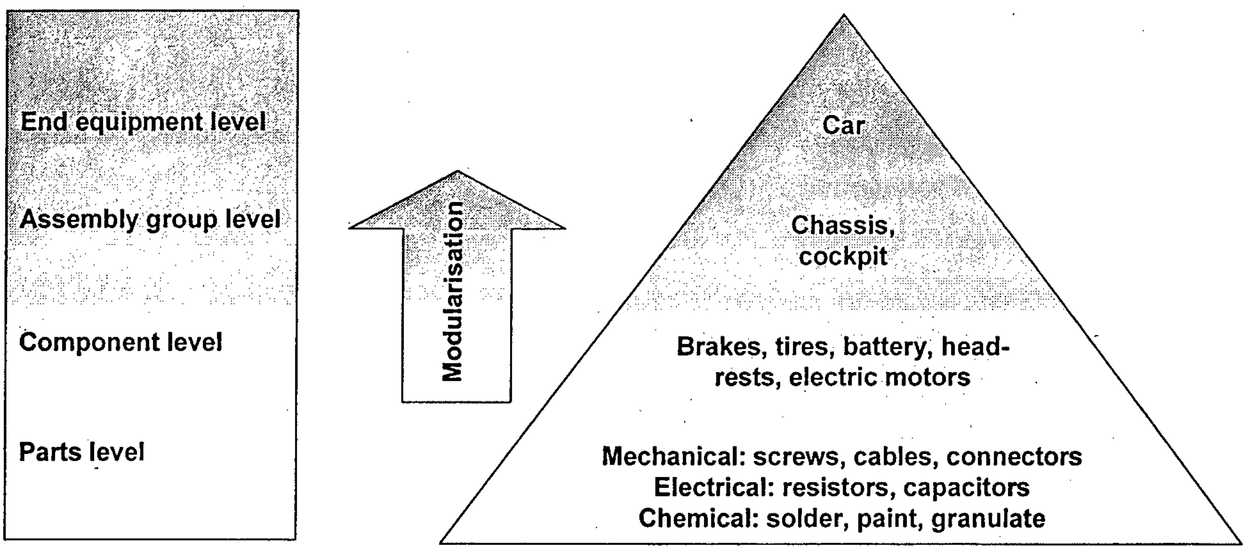

Figure 23: Modularity on different system levels

[83] Due to the fact that these parts mostly have simple functional characteristics (from a technical point of view), the modularisation occurs in most cases only at higher levels.

The contemporary trend in industry is characterised by a reduction in manufacturing depth and a simultaneous concentration on the core capabilities[84]. This trend has also been visible in modularisation and is reflected in the fact that the emphasis of modularisation has shifted from the component level to the assembly group level. Companies are thus trying to reduce the number of their suppliers and to achieve a reduction in the number of their transactions[85].

4.6.1.4 Designing modular products

The procedures in designing modular products are basically the following:

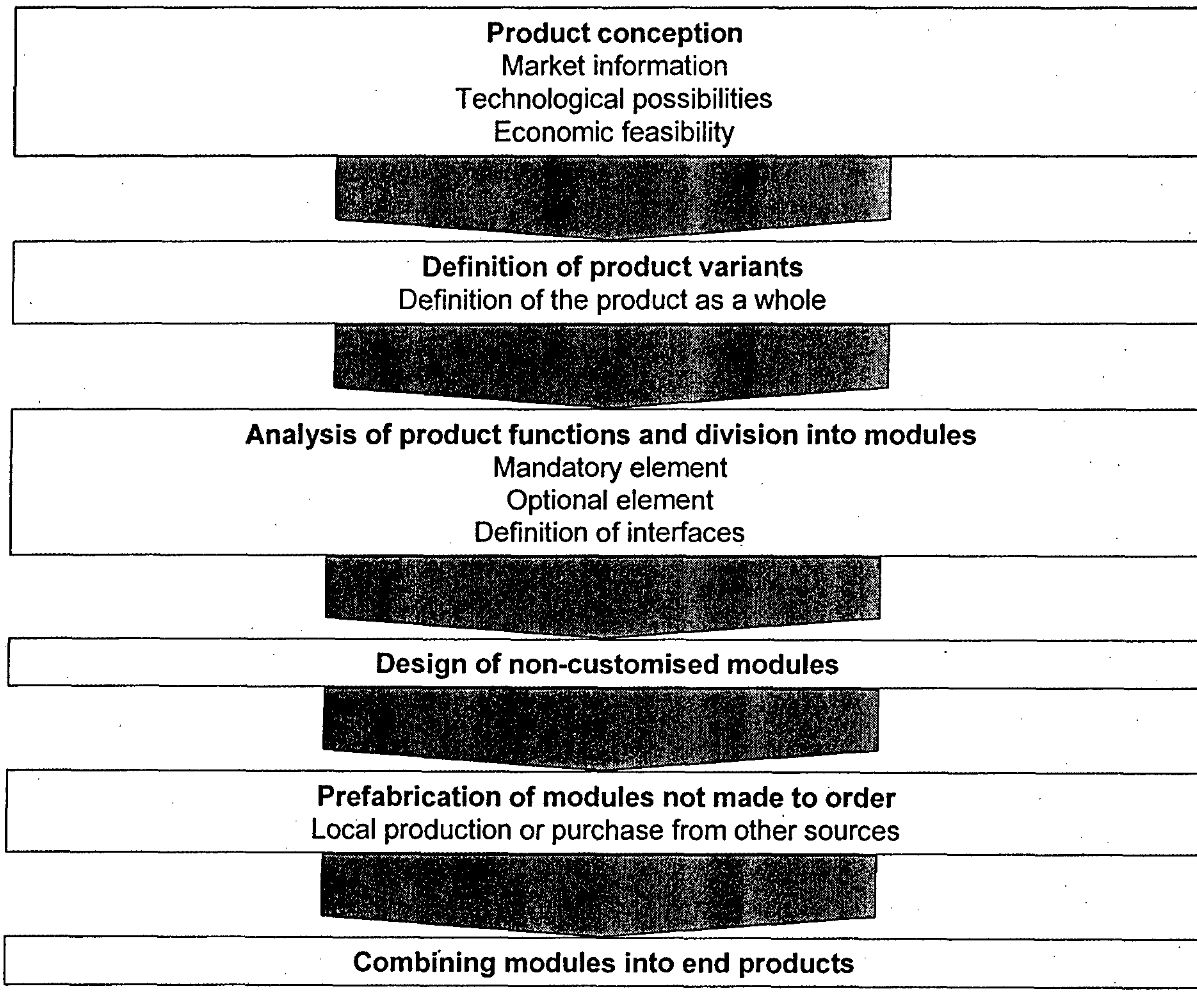

Figure 24: Procedures in designing modular product[86]

In the process of establishing the concept of a product, the particular characteristics of the product are harmonised with the preferences of the potential customer group. In addition to

[84] See Schwalbach and Wolters (1994), p. 38.

[85] In the mid-nineties, the automobile industry, for example, had the aim of reducing the number of suppliers by more than 60 percent and to achieve a three-fold increase in the proportion of modules by the year 2000. See Schwalbach and Wolters (1994), p. 38. Similar figures regarding a reduction in the number of suppliers in the automobile industry can be found in Schindele (1996), p. 78, and Hägele and Schön (1998), p. 70.

[86] Based on Piller and Waringer (1999), p. 57.

determining the customer preferences it is also necessary to gather information about sales volumes and market trends. These data are subsumed under the term "market information".

Other factors that determine the definition of the concept for a product are the company's resources and efficiency considerations. After an analysis of these data, the product range will be determined, and this will depend on the number of variants that are to be offered.

From the totality of possible variants there will then follow the definition of a primary basic product. In the next step, the repeat functions of the basic product will be distributed among the modules. A distinction will then be made between the optional and mandatory modules. Mandatory modules will include functions that are absolutely necessary for the later use of the product; optional modules, on the other hand, will only satisfy those specific customer wishes that go beyond the basic function of the product.

This is followed by the designing of component parts for the construction of the respective modules[87]. In this process there will be an exact, unambiguous and complete allocation of functions to the different modules[88]. Then a decision will be made on which modules are to be produced independent of customer orders. This will mainly affect the mandatory modules, because they will be found in each product and will thus be used more often in the product than the optional modules.

Other decision-making criteria include the number of variants of a particular module and the capital that will be tied up in each of the respective modules. The fewer variants a module has, the more often a certain variant will be used in the product. This will increase the efficiency of the production process when large batches of the product are not produced to order.

For optional modules in which relatively little capital is tied up, the production may also be independent of the customer orders. However, for modules in which a lot of capital is tied up the production will preferably take place only when there are customer orders. At that point a decision will be made on which modules are to be produced by the company and which will be outsourced to suppliers. In the last step, the modules are assembled into the end product.

4.6.2 Effects of modularisation on company processes and competitive strategies

The introduction of modularisation into a company requires thorough preparation. When a decision is made to modularise products, it will first be necessary to consult all the company agencies concerned as well as the customers and suppliers. Demands that will subsequently be made on the product must be incorporated into the system. The system will have to be designed completely from scratch.

[87] See Mayer (1993), p. 159.
[88] See Baldwin and Clark (1998), p. 40.

It is also necessary to develop general interfaces with a sufficient technical growth potential so that possible changes can later be incorporated. Highly innovative products require very extensive interfaces to meet the future requirements. When these design preparations have been completed it is frequently necessary to convert the entire work planning process and production process.

The advantages offered by modularisation include closer customer relations. Customers who have purchased a modularised product from a manufacturer are likely to buy the improved or upgraded modules from the same manufacturer. For the customer this means that if there is a technical innovation he is required to exchange only one module and not the entire product. This may increase the benefit to the customer in the sense of differentiation. Moreover, this increases the operational safety, because if one module fails it will take less time to replace it. In combination with less time-consuming maintenance services this improved repair situation may mean for the customer that he will experience cost reductions in day-to-day operations.

A disadvantage for the manufacturer is that he will incur high costs at the beginning of the introduction of modularisation. Major design efforts are required to meet the demands made on a modularised product. The costs of the product may possibly rise, and it must be clarified in advance whether the customer is willing to bear these additional costs.

Moreover, the modularisation of products will affect the flexibility of a company, because it will not always be possible to satisfy the wishes of customers at a reasonable cost. Thus, in generic and quantitative modularisation it will not be possible to consider any special designs. In the individual and free forms of modularisation, the possibilities in this regard will also be very limited.

As already mentioned, the modularisation of products involves considerable costs. Most of the costs are incurred in the design, in the work planning, and possibly in production if the manufacturing has to be converted. Once the conversion of all work processes is complete, however, there will be cost savings as a result of greater batch sizes and improved quality. The level of costs involved will depend on the number of products manufactured by the company, and on their nature. Design costs will rise as products become more complex.

In the planning, production and assembly phases there is only very limited evidence for any economic advantage from a modularisation of products. In the long run, however, beneficial effects can be expected from more efficient work processes, from reduced training costs, and from quality improvements[89].

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[89] See Wohlgemuth-Schöller (1998), p. 125.

The costs that arise during the process of implementing the modularisation of products are the business risk that occurs when products are modularised. A further calculation that must be made is that there will be technical innovations and changes in the market. If a modularised product can no longer be upgraded, a complete redefinition of the entire system will be required. This in turn involves considerable costs.

The effects of modularisation on the individual competitive strategies can be compared with those of unit assembly systems. The competitive strategy of cost leadership is supported by cost reductions in research and development and in production[90].

Modularisation has very positive effects on the differentiation strategy, especially in the case of the modularisation methods with a high degree of freedom. In this regard the long service life of modularised products must be mention in particular, in addition to the arguments made above in the assessment of unit assembly systems. Technologically obsolete modules can be exchanged at low cost, which guarantees a high level of functionality in the longer term.

4.6.3 The influence of product, company and market related factors on the beneficial effects of modularisation

Product-specific factors

A major advantage of the modularisation of products is that modules can be exchanged easily. If the function of a module no longer completely satisfies the user's needs, the module can be replaced by another module at a relatively low cost. In such a case, however, conventional products will often have to be replaced, as well, which can lead to comparatively high costs. The benefit of using a modular product thus rises with the level of its purchasing price, the length of the prospective service life, and short innovation cycles in the primary functions.

Company-specific factors

Like unit assembly systems, modularised products can be manufactured in big batches, independent of any specific orders. This increases the productivity, especially in the highly automated processes like duplicate or continuous production. This advantage rises steadily as the relative share of the manufacturing process in the value-added process increases. It is also possible, as part of an outsourcing strategy, to shift work-intensive design tasks to suppliers.

Market-specific factors

Due to the exchangeability of modules, modularised products can be used in a very flexible way. The extent to which the criterion of flexibility influences the purchasing decision of the customer is therefore a decisive factor. Other advantages of modularised products are their low susceptibility to breakdowns, uncomplicated maintenance, and short delivery times.

4.7 Quality management systems (ISO 9000 to ISO 9004)

To this date, numerous companies have adopted many different types of quality management systems. One QM system has become particularly well known, not least due to the fact that it is internationally applied. The standards on which this QM system is based are DIN EN ISO 9000 to 9004. ISO 9000 is a quality management and quality assurance standard, but it also is a guideline for the selection of one of the models described in ISO 9001, ISO 9002, and 9003. These standards describe models for quality assurance in the following areas:

- ISO 9001: Design and development, production, assembly, and maintenance;
- ISO 9002: Production, assembly, and maintenance;
- ISO 9003: Final testing.

Companies are free to choose the model according to which their quality assurance system is to be introduced and certified.

ISO 9004 provides the elements of the quality assurance system. They are described in
- Part 1: Guidelines, and
- Part 2: Guidelines for Service Providers.

These standards provide the companies with uniform guidelines for an optimisation of those recurring activities that are repeatedly performed over and over again many times. However, it should be noted that this will help the companies to optimise only the performance of such operations. It is unfortunately a frequent misconception that a quality assurance system will automatically help a company to improve the "quality"[91] of its product or services.

When such a system is to be implemented it is necessary to make decisions for these areas:
- Quality policy,
- Quality management,
- Quality assurance system,
- Quality control, and
- Quality assurance.

As this list indicates, only the activities in these areas are defined. Basically, all that can be done with a QM system is to document the fact that a product is of poor quality. Alleviating such a problem can only be done with further measures, e.g. instructions from the company management for the necessary actions.

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[90] Blohm + Voss estimate that the cost reductions achieved in the development and design of modularised MEKO frigates and patrol escorts amount to about 12 percent.
[91] Definition of "quality": The totality of the characteristics and features of an element with respect to its suitability to satisfy the given requirements.

To minimise these "friction losses", ever more companies decide to establish a QM system and to prepare for certification without, however, taking advice from external consultants. The particular benefit they expect from taking this approach is that their own staff is directly involved in the implementation[92]. This way the companies are trying to avoid an inadequate implementation of the required measures. In a worst-case scenario, improper implementation could lead to a "make-belief QM system" that was implemented successfully only on a formal level, but in practice it would not lead to improvements in product quality.

The reason for this negative development is the certification process, and the certifiers are responsible. Certifications are performed by an increasing number of authorised certifiers. Due to the rising pressure of competition, the certifiers are trying to reduce their costs and to increase their profits by using pre-designed systems. The result is a decline in the quality of QM systems, because the pre-designed systems do not take the specific characteristics of the individual companies into consideration. Whether a certification system was individually designed or not cannot be determined *a priori* because most certifiers use a similar approach, and the documents they use are identical in form. The process consists of four main phases:

- Filing an application,
- Optional pre-audit,
- Review of the documents,
- Audit at the company.

The steady decline in the quality of QM systems has caused some companies to consider developing their own QM system. The intention is to bring about a higher quality level within the company than could be effected with the QM systems provided by the certifiers. Once a company is ready to make the decision to establish a QM system, the management will have to make decisions on the following:

- Management responsibilities,
- Quality management system,
- Contract review,
- Design control,
- Document and data control,
- Procurement,
- Control of customer-supplied products,
- Identification and tracing capability,
- Process control,
- Testing,
- Master tool control,
- Inspection and testing status,

[92] See Hesser (1997), Chapter 3.1.

- Control of nonconforming products,
- Corrective and preventive action,
- Handling, storage, packaging, preservation, and delivery,
- Quality records control,
- Internal quality audits,
- Training,
- Maintenance (customer support),
- Statistical methods,
- Quality costs,
- Product safety and product liability[93].

After these points have been clarified, the implementation of a QM system can begin.

4.7.1 Effects of QM systems on company processes and competitive strategies

There are only limited possibilities for a quantitative measurement of the economic benefit from the installation of a QM system; however, many arguments are being used to indicate that there are economic benefits from a QM system. For example, many companies evaluate their suppliers on the basis of whether they have established a QM system[94]. This results in a "restricted access" to the market or in a "de facto standard". By introducing a QM system the company can try to circumvent such trade barriers. Certification can also be used as evidence of the quality of the documentation in a company. However, introducing a QM system into a company can disturb the existing information channels and processes in the company. This is a disadvantage, because the staff will first have to become familiar with the new instructions; thus there may be friction losses shortly after a successful implementation. Another factor to be mentioned in this context is the relatively high costs of implementing a QM system.

The costs connected with the implementation of a QM system stand in direct relation to the products manufactured or the services provided by the company. Nevertheless, it is possible to make some general statements with respect to costs. The certification costs are estimated to be about € 15,000 to € 125,000. The internal costs for the company are about € 50,000 to € 500,000[95]. According to Sprenger, small businesses in Germany pay at least € 5,000, while medium-sized businesses pay up to € 23,000 and large companies will pay several € 100,000. Jütting has determined, with reference to studies made in several medium-sized companies that about 75 percent of the costs of implementing ISO 9001 are internal costs, while about 25 percent of the costs are due to the respective certifier[96].

[93] See DIN EN ISO 9001, Section 4.
[94] Motorola, for example, has excluded all suppliers who do not take part in the competition for the Malcolm Baldridge National Quality Award. See Wright et al. (1992), p. 125.
[95] See Postinett (1996), p. 19.
[96] Cited from Jütting, Korn and Möbius (1993), p. 34.

The time-frame that has to be established for the implementation of a QM system depends on the size of the company and is about 5 to 15 months. This implies that for small companies a certification may be possible within a shorter period of time.

The purpose of improving the quality management in a company is to obtain a competitive advantage in the medium to longer term. A company which is not satisfied with obtaining a certification but which subjects its products to a continuous improvement process will have such a competitive advantage[97]. If the certification is not performed by a competent certifier, there will be risks for the company. Such certifiers frequently use pre-designed concepts that are quickly and easily implemented, but may not be applicable to the specific characteristics of the respective company. In such a case there is the danger that an ineffective QM system is implemented. While such a system exists on paper, it will not have any effect on the quality of the company's products.

The implementation of a QM system gives a company the chance to improve all processes in the company; however, at the same time, such a reorganisation also implies a major risk[98]. In the long term the high cost of implementing the QM system is compensated by a lower reject rate and a reduced amount of services provided as a result of warranty obligations. This will support the competitive strategy of cost leadership[99]. The differentiation strategy is supported by the improved product quality and the positive image of companies that have been certified.

4.7.2 The influence of product, company and market related factors on the beneficial effects of quality management systems

Product-specific factors

The extent to which the implementation and certification of a QM system can improve the product quality mainly depends on how the QM system is implemented in the company. In particular, the parts, assembly groups and components that fulfil primary product functions should have a low susceptibility to breakdowns. This aspect is even more important where safety functions are concerned. For example, the demands that must be met by the quality of materials, parts, assembly groups and components may be disproportionately high. Further product-specific factors are the complexity of the product structure and the value of parts and components used. If the product structure is complex, the detection and correction of faults is often difficult and may involve considerable costs. In the case of products which have a high material value there may be considerable amounts of "sunk costs" involved if faulty products are not selected out for rework.

[97] See Hesser (1997), Chapter 3.1.
[98] See Hesser (1997), Chapter 5.
[99] Motorola estimates that the decline in warranty services that was due to improved product quality amounted to a value of \$ 250 million within a two-year period. See Wright et al. (1992), p. 125.

Company-specific factors

Faulty parts, assembly groups, components and products may have serious consequences for the production process. In highly automated processes such as continuous production, faulty parts may cause a temporary standstill of the entire assembly line and can cause considerable losses in production. Another criterion is the number of stages through which a product goes during the manufacturing process, because an increasing input in the production factors will increase the loss of value that is caused by faulty products.

Market-specific factors

Frequently suppliers are even more subject to market forces than are the companies which produce directly for end users. Due to this dependency, suppliers may be forced to implement a certified QM system if the downstream companies demand this. If a company can improve the quality of its products with a QM system, it will have better opportunities in the market for the long run, particularly in customer segments which demand high quality.

4.8 Environmental management systems (ISO 14001 and EMAS II)

Environmental management systems are primarily used for the continuous improvement of a company's environmental protection standards. For the companies this involves the necessity to know those activities, products and services that may interact with the environment. These environmental aspects must be determined and subjected to a critical review. Particularly in economically difficult times, effective environmental management will give a company the chance to hold its ground against the competition. Economic crises situations demand new processes, new products, and new markets. In this context, the environmental quality of the value-added process and especially of the product is a decisive criterion for future success[100].

Currently, companies have two instruments available for establishing and evaluating company environmental management systems:

- EMAS II (EEC Regulation 761/2001: EEC Rules for Ecological Audits), and
- DIN EN ISO 14001 (international environmental management standard).

These systems may be integrated into QM systems established in accordance with the new standard, DIN EN ISO 9001:2000.

Companies generally install an environmental management system on a voluntary basis. In many cases, however, some pressure may be applied to introduce such a system. This may occur, for example, when large companies demand that their suppliers furnish proof of the existence of an environmental management system. The reason is that these companies are

[100] See *Handbuch Umweltcontrolling* (1995), p. 7 ("Environmental Controlling Handbook" published by the Federal Ministry for the Environment and the Federal Environmental Agency).

themselves held liable by their banks and insurance companies, via specific liability and risk classifications and corresponding insurance rates, for any environmental damages that may be caused by their products. Moreover, certified companies can expect some relief from rules in regulatory law, because such companies may be exempt from certain reporting obligations[101].

Environmental management may be defined as follows:
"Environmental management includes the planning, control, monitoring and improvement of all company activities related to environmental protection as well as an environment-oriented style of industrial and human resources management[102]."

Environmental audits

The central element of any environmental management system is the environmental audit. The aim of the environmental audit is to conduct the regular control, evaluation and further development of an already existing instrument for handling environmental protection issues. Such controls may be performed in the form of audits. The procedure was standardised by the European Union (EU Regulation 1836/93) and the International Chamber of Commerce.

The effects, functions, purposes, objectives, aims and substance of an environmental audit can be summed up as follows:

	Internal Effect	**External Effect**
Function	Internal audit, planning and control	Means of conducting PR work
Purposes / Objectives / Aims	Identify the technical requirements; evaluate environmental management tools; verification instrument; precondition for making acquisitions and for a grant of loans	Present the company as environmentally aware and technically reliable; improve the company's environmental image, reputation, and credibility; promote dialogue with reference groups
Contents	Check facilities and management systems	Voluntary publication of data; certification

Figure 25: Target groups and effects of environmental audits[103]

The effects on the environment can be determined with an ABC/XYZ analysis[104] or by the preparation of an ecological balance sheet. An ecological balance sheet is a highly complex and comprehensive instrument for an objective determination of the environmental impact of the object that is being examined. The objects can be both products and services. Ecological balance sheets consider the entire life cycle of the object being examined. Thus they provide an opportunity to determine optimal flows of substances and energy, from an environmental point of view, and to define optimised processes and process sequences[105].

[101] See Hesser (1997), p. 8.
[102] Quoted from Kamiske et al. (1995), p. 4.
[103] See Hopfenbeck and Jasch (1993), p. 151.
[104] A more detailed description of the ABC/XYZ analysis is found in Kamiske et al. (1995), p. 55.

The theory for this procedure has already been developed, but at the present time it is applied only sporadically in practice. The reason is that to this date no exact directives or instructions have been developed by which it would be possible to prepare such ecological balance sheets. So far there exists only a general procedure for the preparation of an ecological balance sheet.

The preparation of an ecological balance sheet consists of the following four steps:
1. Determining the flows of substances,
2. Classifying the types of impact,
3. Weighting the environmental impacts, and
4. Evaluating the options for making improvements.

[105] See *DIN-Fachbericht 51* (Technical Report 51, 1996), p. 70.

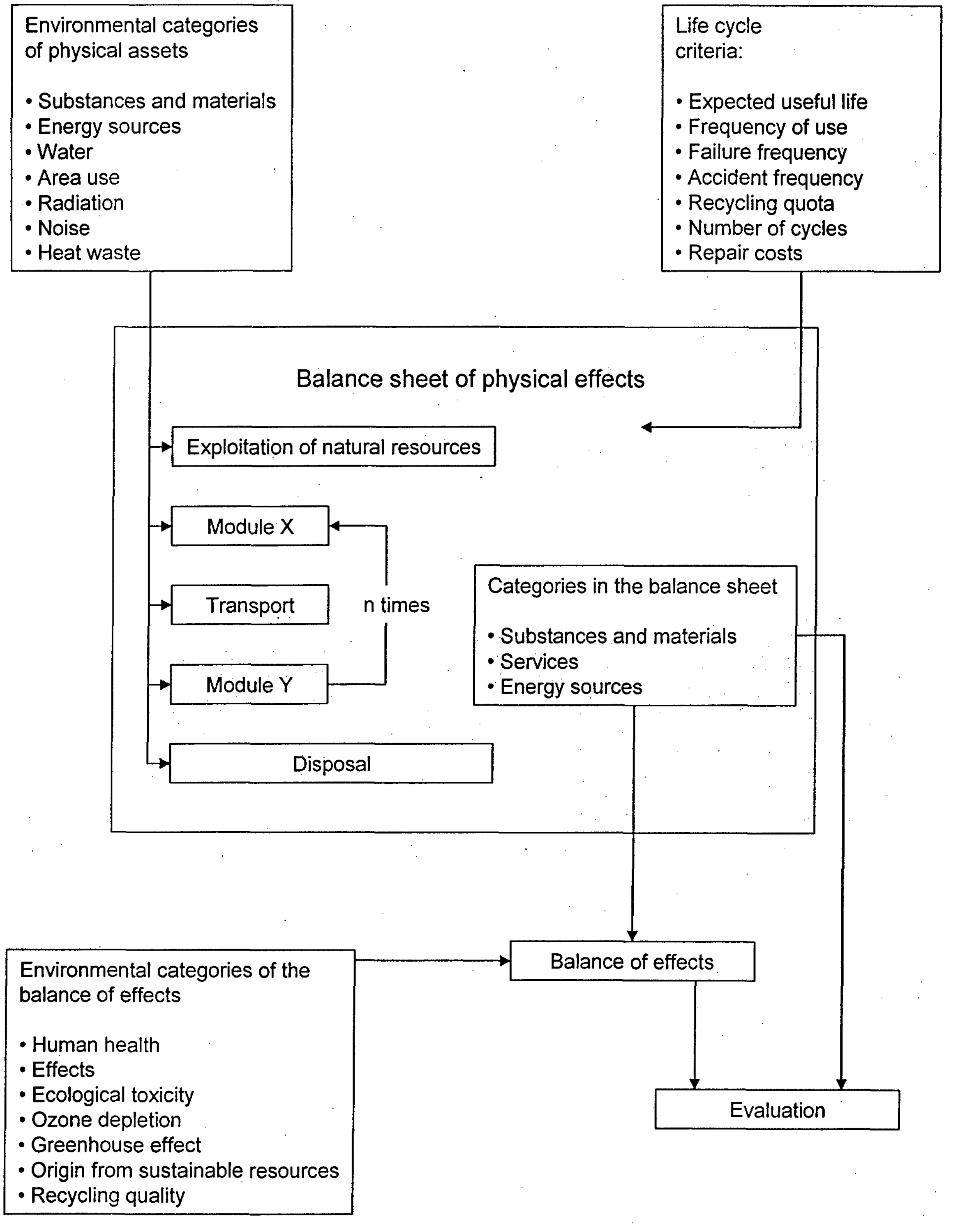

Figure 26: Model of an ecological balance sheet[106]

[106] See Kamiske et al. (1995), p. 81.

This model ecological balance sheet was developed by the Federal Environmental Agency (UBA – *Umweltbundesamt*) and the DIN working group on Life Cycle Analysis. It can be used as a concept for the product balance sheets.

Many companies are making efforts to take environmental criteria into consideration in designing their value-added process, and they want to have this effort properly recorded. They do this not least with a view to the ever stricter environmental legislation and due to the fact that there is a general increase in environmental concern among interested parties.

In this context, on 21 August 1996, the European Standards Committee (CEN)[107] has adopted a European standard which states the following:

"The purpose of issuing the international environmental management standards is to provide organisations with elements of an effective environmental management system which may be combined with other management requirements to support the organisations in their effort to achieve both environmental and economic goals. These standards – like other international standards – are not intended to establish non-tariff trade barriers or to increase or modify the legal obligations of these organisations[108]."

For their practical environmental management the companies basically have the option of establishing an environmental management system in accordance with the requirements of these international standards and regulations. In the international arena, the companies can use DIN EN ISO 14001 for this purpose. The companies of the European Union have the alternative of having their environmental management system validated in accordance with the so-called "EMAS II" regulation. The evidence of the successful implementation of this standard or regulation can be used by the companies to provide interested parties with proof of the fact that they have implemented an effective environmental management system[109].

Our objective in the context of this paper now is to clarify the question of how a certification according to DIN EN ISO 14001 or a validation according to the EMAS II regulation can be supportive in the competitive strategies of companies.

[107] European Committee for Standardisation, Comitè Europèen de Normalisation.
[108] Cf. DIN EN ISO 14001 (1996), p. 3.
[109] Ibid.

4.8.1 Effects of certification or validation of an environmental management system on company processes and competitive strategies

Through the implementation of an environmental management system, companies generally pursue the objective of improving their environmental performance. Their concrete aims in this context may be the following[110]:

- To implement, maintain and improve an environmental management system;
- To ensure conformity with a self-proclaimed environmental policy;
- To give evidence of such a conformity to others;
- To have the company management's efforts certified by an external organisation;
- To determine and declare that the company is in conformity with international standards.

By installing an environmental management system, the companies may be exonerated from certain obligations of documentation and reporting, verification procedures, and inspections. Another advantage is in the product differentiation, because customers often take ecological aspects into consideration when choosing the products they wish to buy. The certifiers who perform the implementation of environmental management systems often cite the following additional advantages:

- Reduction of direct environmental costs;
- Deliberate use of environmental subsidies;
- Facilitation of credit grants;
- More systematic environmental protection efforts within the company;
- Avoidance of violations by the organisation;
- Preparing for stricter environmental conditions;
- Competitive advantages; and
- General satisfaction of customers and staff.

These sources naturally do not list any disadvantages. In this context, however, it is necessary to also consider the costs caused by the introduction of an environmental management system. In addition it is frequently necessary to make structural changes or to modernise the divisions of the corporation to achieve the ecological objectives.

The costs incurred will again depend on the size of the company and the length of time required collecting the data. In a pilot project conducted by the state government of Hesse, from 1993 to 1995, fourteen companies were given support in their effort to introduce and conduct an ecological audit. The costs incurred were from € 7,500 to € 58,000 for each company. Other sources state auditing costs of € 25,000 to € 500,000 in pilot projects[111].

[110] Cf. DIN EN ISO 14001, p. 6.
[111] Cf. Hesser (1997), Chapter 3.2.

In the short term the introduction of an environmental management system will have effects on a company only if the required information is already available and if it is possible to start the implementation immediately. In the medium to longer term, if a company has a certified or validated environmental management system, this may lead to an ecological improvement in the overall performance of the company. If customers decide to reward the company for the improvements by making the appropriate purchasing decisions, there is a differentiation advantage.

If an environmental management system has been implemented and is certified or validated, the company concerned can make use of this fact for advertising purposes and use a so-called "eco-logo"[112] which can be used to achieve another differentiation advantage.

The certifiers frequently state that there are cost savings that can be achieved through the introduction of an environmental management system, such as reduced direct environmental costs and a deliberate use of environmental subsidies and assistance funds. Although these claims are correct, these cost savings cannot always be offset completely by the actual costs of implementing such a system. Nevertheless, there is clearly no general negative influence of certified or validated environmental management systems on the cost leadership.

This will be demonstrated in the following sections, where we will cite some examples of successful environmental management by a company of the European aerospace industry[113].

4.8.2 The influence of product, company and market related factors on the benefits from the certification or validation of an environmental management system

Product-specific factors

The extent to which it is possible to improve the environmental impact of products through the implementation and certification or validation of an environmental management system mainly depends on how this is implemented within the company. The guidelines provided by DIN EN ISO 9000 to 9004 and the EMAS regulations permit taking a structured approach to the implementation of an environmental management system.

From an ecological perspective, the application of these standards and these regulations must therefore be regarded as a positive development. All products cause emissions that will have more or less environmental impact during the development, in-service and disposal phases of the product. As these emissions increase during each of the respective phases, there will then be an increasing necessity to reduce these emissions from the product to a degree that can be considered environmentally compatible.

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[112] A use of the "eco-logo" is possible only to a limited degree; for example, advertising with it on products or packaging is excluded.
[113] The cost-reducing effect of environmental management measures is documented in many publications. Examples are: Hansmann (1994a), Gege (1997), and Bickhoff (2000).

Company-specific factors

The annual volume of waste and the resulting disposal costs can be considered as a company-specific factor. This applies in particular to critical waste, which often entails high costs for a disposal which is environmentally compatible. Another important criterion is the amount of energy required for this purpose.

Market-specific factors

The fact that typical suppliers are highly dependent on downstream companies may be an important argument in favour of a certification or validation. For companies whose products are purchased directly by the end user, there is the question as to what extent the customer segment they serve will reward them for environmentally compatible products, or to what extent the customers take the environmental policy of companies into account when they make their purchasing decisions.

In this part the instruments of in-company standardisation have been outlined in detail and the impact of product-, company- and market-specific factors on these standards has been discussed. In the following part some examples of possible applications of in-company standards and their impact on competitive strategies are given.

Summary chapter 4

In this chapter we took a detailed look at different in-company standards. Beside well-known acknowledged standards as ISO 9000ff. and ISO 14000ff., other in-company standards, such as modularisation, unit assembly, size range and numbering systems or class lists of subject characteristics, were described and analysed with regard to their impact on the competitive strategies of cost leadership and differentiation. The following chart contains the most important results. Furthermore we assessed the influence of company, product and market-specific factors on the beneficial effects of the discussed in-company standards.

	Cost leadership	Differentiation
Class lists of subject characteristics and feature lexicon	• support the search for repeat and identical parts and permit concerted searches for comparative cheap standard parts, • reduce the costs of time-consuming and cost-intensive new designs, new drawings and production plans.	• reduce the reaction time required to manufacture a product (time to the market), • increase the quality of products, because the reused existing parts are technically sound.
Numbering systems	• reduce the variety of parts.	• reduce the reaction time for responding to customer requests in the spare parts service and improve the customer services.
Size range systems	• simplify the cost-intensive development of products, • reduce the number of designs and increase the production batches (economies of scale), • support the use the same materials, which reduces procurement costs and permits using the same tools.	• support the production of goods with a low failure rate.
Unit assembly systems and modularisation	• increase the flexibility in production and allow the production of bigger batches.	• improve the quality (low failure rate)of the products, • facilitate the service and maintenance of the products, • improve the spare parts supply.
Quality management systems	• can lower the reject rate, • reduce the amount of services provided as a result of warranty obligations.	• improve the product quality, • improve the image of companies.
Environmental management systems	• reduction of direct environmental costs, • avoidance of violations by the organisation.	• improve the image of companies, • improve the ecological features of a product.

5 Examples for the use of in-company standards to facilitate competitive strategies

5.1 Environmental management systems: Environmental protection in the context of competitive strategies

In the past, companies performed their environmental protection measures mostly after the impact on the environment. Such environmental protection measures are referred to by the term "additive environmental protection measures". Another term that is frequently used in this connection is "end-of-pipe process" (EOP).

EOP technologies are environmental protection technologies that are used to treat emissions and wastes from production processes after these have been generated, and to reduce their potentials for causing ecological damage. The emissions that have been generated may thus be treated (for environmental reasons) by using filters and catalysts.

EOP technologies are frequently less efficient than are integrated technologies, because the latter are intended to avoid negative environmental effects, and thus disposal costs, right from the start. The advantage of using EOP technologies primarily lies in their better feasibility. Figure 27 provides some arguments for the introduction of EOP technologies.

Advantages of EOP Technologies

- Less uncertainty with regard to the characteristics of the emissions reduction.
- Lower access costs due to successful testing (the technologies do not need to be developed by each individual company, but can be used by different companies).
- Lower costs in the conversion of existing technologies, compared to the costs of integrated environmental protection technologies.
- Lower failure probability of the proven EOP technologies, and thus reduced technical and economic risks.
- Better options for selling residual materials.

Figure 27: Arguments for the traditional predominance of EOP technologies[114]

Additive environmental protection measures are mainly applied in order to meet the minimum standards required by law. They include the following activities[115]:

- Air pollution control,
- Waste-water treatment,
- Waste treatment,
- Noise protection.

[114] Cf. Kreikebaum (1992), p. 11.
[115] Cf. Strunz (1993), p. 98.

The disadvantage of taking additive environmental protection measures is that the respective measures are not adapted to the source of the negative environmental impact per se, but only to the environmental problems it has caused. Thus the procedures that are being applied are not optimal from an ecological point of view. However, the new approach that is reflected in the greater use of integrative environmental protection measures is accompanied by a stronger emphasis on the sources of environmental pollution[116].

This new formulation of the problem also leads to different requirements for environmental management systems. The new requirements that an offensive and preventive environmental management system must satisfy are the following:

- Environmental protection must be adopted as a paramount corporate objective.
- Environment-oriented corporate policies, programs and practices must be integrated into all management functional areas, as essential elements of corporate management.
- Environmental protection must become a concern of the top management; this means that the management board must appoint a person who is responsible for environmental issues.
- An absolutely necessary precondition for this is to establish a permanent information and training program for the staff.
- The aim should be a continuous reduction of emissions; a prerequisite for this is a steady and continuous monitoring and analysis of all processes taking place in the company[117].

These requirements can only be satisfied, of course, if an efficient system is installed which will on the one hand include all divisions of the company (and maybe even elements outside the company, such as suppliers, etc.), and on the other hand allocates the required authority such that the necessary measures can be taken.

The following section will describe preventive environmental protection measures and the beneficial effects that can be achieved for companies through an effective environmental management program.

5.2 Environmental protection measures at the European Aeronautic Defence and Space Corporation

The European Aeronautic Defence and Space Corporation (EADS) is a producer of civilian and military aircraft and of aeronautical and space systems. It has a workforce of more than 100,000 employees worldwide. In 2001 it had a total sales volume of € 30.8 billion.

At EADS, the environmental compatibility of its products is an important consideration, as is reflected in a variety of measures the company has taken in environmental management, some of which are described below. The aim is to show how environmental management measures

[116] For example, a hydrogen-powered motor vehicle does not need a catalytic converter.
[117] Cf. Kamiske et al. (1995), p. 5.

can support a company's competitive strategies and can thus make a sustained contribution to the company's commercial success.

Recovery of plastic materials

At the EADS Airbus Company plant in Stade, Germany, the company uses a fully automatic horizontal canal baler to recover plastics that are turned into waste material in the production process. This machine staples plastic-sheet waste material (separated according to whether it is polythene or polyamide) and ties it into bales. The advantage that this machine offers is that it permits choosing the size and weight of the bales in accordance with the requirements of the companies that dispose of the waste material, so that the companies which re-use the plastics can process the bales at their facilities without problems. By separating the different types of plastic and dimensioning the sheet waste in such a way that it is tailored to the needs of companies that process the waste, it is possible to obtain higher revenues; in this case it is about € 300 per ton of plastics. The introduction of this system has also made it possible to realise another feature that benefits the environment: By optimizing the load density of the bales it was possible to save transport capacities and to reduce the costs and waste gases.

Another material that is being processed at the Stade plant is carbon-fibre reinforced plastic (CFRP). These relatively expensive composites – 1 kg of raw material costs about € 60 – are used to manufacture aircraft tail assemblies that are subject to high levels of stress. Although the systems used to cut the material to size already work in such a way that the cutting process is optimised, the process generates about 400 kg to 500 kg of CFRP waste material per day.

Until a few years ago, this waste (a highly valued raw material) was refined for re-use in a thermal process. The problem with this was the collision of the carbon fibres with the electric filters used in the incineration process. In the meantime, a new process has been developed in which the cuttings are re-used partly as a raw material by an external disposal company using a pyrolysis method[118], and partly re-used as industrial material. The revenues from the sale of these waste materials are clearly higher than those obtained from the thermal re-processing.

Recycling plastics

Due to the high quality standards in aircraft construction it is rarely possible to use recycled material in the manufacture of aircraft. However, a good example of the re-use of recycled material at EADS Airbus is the production of fairing parts for the door areas of aircraft[119].

In this application, parts are manufactured from PPSU (polyphenylene sulphone), which is an expensive and technically high-grade thermoplastic deep-drawing material. In this process, relatively large amounts of waste are generated. This PPSU waste is separated by type of

[118] Details on the pyrolysis process are contained in Wiezorek (1993), p. 42.

[119] Generally we can distinguish between four different types of recycling. The classification is based on the degradation of material quality and distinguishes between re-use, further use, recycling, and further processing. See Rötzel-Schwunk and Rötzel (1998), p. 80.

material and is then returned to the manufacturer of the semi-finished product, who uses this waste to manufacture material for the production of fairing elements.

Such waste processing helps to preserve resources and makes sense from an environmental point of view; however, it should also be judged favourably from an economic point of view. The semi-finished products manufactured from recycled material have the same qualitative standard as the previously used material, but compared to the previously used material they cost only half. In 1998, this measure helped to save more than € 75,000 in material costs.

Reduced water use through circulation systems

At the Bremen plant, which is the EADS Airbus Company's centre for fitting out the wings of all wide-bodied aircraft and for the production of small metal sheets, the process of cleaning work-pieces with water was technically modified in such a way that the water consumption at the plant was reduced. The system in this concrete case was a crack detector that was used to check aircraft parts for cracks that cannot be detected with the naked eye. The detector was primarily used to check welded parts and critical formed parts. After these parts are cleaned with ultrasound and are then completely wetted with a fluorescent crack testing medium it is possible to detect cracks under an ultra-violet lamp. After the testing was finished, the crack testing medium was rinsed away with water.

The waste generated by this process had to be disposed of very carefully, and this involved very high costs. For this reason the system was equipped with an ultra-filtration unit so that the polluted waste-water could be cleaned and re-used through a circulation system. With the help of this water circulation system it was thus possible to reduce the use of costly drinking water at this facility from the former 40 m^3 per annum to 4 m^3 per annum. The ultra-filtration process also reduces the amount of waste that must be monitored, and thus the cost of waste disposal was reduced to about one tenth of the original cost.

Reduced use of cooling lubricants

At the Airbus assembly plant in Hamburg, Germany, about 60 litres of synthetic cooling lubricant were formerly required for the bore-holes on one wing-fuselage break-in. Due to technical modifications at the drilling unit it was possible to convert to the use of a biological cooling lubricant that is based on a vegetable oil. Due to this improvement, not only does the new product have a better environmental compatibility, but the amount of lubricant required in this work operation was also reduced by 66 percent. Moreover, the cost of purchasing the biological cooling lubricant is cheaper by one third when the same quantity is purchased.

In another project, the environmental compatibility of the so-called "portal milling machines" that are used to manufacture aircraft parts from aluminium, steel or titanium blocks has been improved. After these work operations, the manufactured parts have only about 15 percent to 20 percent of the material contained in the original block. The remainder consists of chips that are separated by type of material and are then supplied to the recycling process.

The problem here was that the chips were mixed with the cooling lubricant. The chips were transported in a partly open circulation system, so that about one third of the emulsion was lost in the process, due to evaporation and chip drag-out. To reduce this loss of lubricant, a technical solution was implemented that differs from the previous process.

This solution involves the extraction of chips in a vacuum and then breaking them up into small bits in a centrifuge before collecting them for recycling purposes. To save energy, the extraction is performed only when chips are actually produced. The cooling lubricant is then pumped back and kept in circulation via a reprocessing plant, which considerably increases the service life of the emulsion. Due to the use of this system, there is a considerably lower emulsion content remaining on the chips. Since the chips are also smaller and lighter, the disposal company is willing to pay a higher price for them. This system is now standard in the entire production hall. The cost of introducing this measure was about € 1.05 million.

Advanced varnishing systems and varnishes with less dissolver

In the industry there are many different systems in which varnishes are used. The dissolvers released from these varnishes make up a high percentage of the emissions of volatile organic compounds (VOC). The reduction of dissolver emissions from varnishes is an important task for all companies that handle paints.

This is the context in which EADS Airbus decided to use a new pollution-reducing varnishing system. It was necessary for EADS to make this investment because some American airlines had specific preferences for aircraft in which varnishes with low dissolver content are used.

Within one year, EADS doubled its sales volume of aircraft in which these varnishes were used. Today, more than two-thirds of all aircraft are coated with low VOC varnishes. This example shows that a well-directed environmental protection measure can be used to gain a differentiation advantage and a sustainable improvement in competitiveness.

Replacing light bulbs with light emitting diodes

In the past, each Airbus A340 aircraft was equipped with 1,000 light bulbs just to illuminate the NS/FSB signs ("no smoking / fasten seat belts"). The average service life of such a light bulb is 250 flight hours. At an average of 4,000 flight hours per aircraft per year, one aircraft alone thus required 16,000 light bulbs. EADS estimates that the total cost of this per aircraft and year was about € 50,000.

To reduce these costs, the light bulbs in all aircraft types are now being replaced with LEDs (light-emitting diodes). The long service life of an LED permits using it during the entire in-service phase of the aircraft. Not only does this make it possible to achieve the primary aim of cutting costs; it also contributes to the reduction of waste.

Smoke detectors without radioactive material

In aircraft construction, often materials are used for which the disposal is highly problematic and associated with high costs; however, due to the specific properties of these materials it is partly not possible to do without them. Nevertheless, smoke detectors provide an example of how such substances can be eliminated. In the past, smoke detectors contained a radioactive material that was very difficult to dispose of. Now, these smoke detectors have been replaced with new ones that work on an optical basis.

Environmental protection in product design

In the search for potential areas in which negative environmental impacts can be avoided or reduced, the manufacturing process (particularly at production plants) plays a dominant rôle. But a second functional area where such potentials can be found is the area of design. This will now be examined and illustrated with an example from EADS.

The environmental impact of products during their development and in-service phases is a criterion that increasingly influences the purchasing decisions of potential customers. The companies must react to these new market conditions to maintain their competitiveness. Many companies are therefore employing integrated environmental protection measures to prevent negative environmental impacts of their products.

The environmental compatibility of a product is almost completely determined during the design phase. In this phase, not only are the characteristics of the product established, but also the processes that are required to manufacture the product. In order to be able to take the economic goals sufficiently into consideration during the design process, specific instruments are required to support an economically and environmentally sound design. For this purpose, EADS Airbus initiated its "TUKAir Project" (TUKAir = *Team umweltgerechte Konstruktion Airbus*, or "Team for an Environmentally Sound Airbus Design"). The objective of this team is to suggest possible approaches and find solutions for the realisation of an environmentally sound aircraft design. One focal points of the team's work is to analyze the environmental compatibility of parts that are already used in aircraft.

The example below is intended to demonstrate, on the basis of an ecological evaluation of an auxiliary frame, two possible technical solutions and their different effects on costs and on the environment.

Starting points for and tasks of the team for an environmentally sound design

As is true at many other companies, for a long time the activities in the area of environmental management at EADS Airbus Company were focused on the production process. However, to achieve a more holistic approach to environmental management, EADS found it necessary to bring about a reorientation so that the design process would become better integrated into the process as a whole.

In addition to the traditional criteria for the evaluation of a product, such as functionality, production methods, and cost-effectiveness, the environmental compatibility of a product has become increasingly important as a fourth criterion. It has therefore become necessary to develop methods and processes to support an environmentally sound design already during the development process.

The purpose of the TUKAir Project is not to deal with technological topics or to look at the product as a whole under the aspect of an ecological balance sheet[120]. Rather, the goal is to develop general principles of action in an effort to achieve an environmentally sound design, to review the instruments used to determine whether they are still applicable, and to verify the results in a pilot project.

To achieve this goal it was first necessary to provide a definition of the term "environmentally sound design" that is binding on the company. Thus, an "environmentally sound design" was understood to be the creation of a product without the use of much material or energy during the production, a product that saves energy in all its life-cycle phases (production, operation, out-of-service phase), and a product that has good re-use and re-cycling capabilities.

As an example of environmentally sound design we can take the C 58 an auxiliary frame in the cargo door frame of the A330/340 type aircraft. For the production of this frame, two alternative design options were identified. These options were the previously used variant, which used a riveted differential construction, and an integral construction which involves milling the part out of one piece. This was followed by an evaluation of the two design versions.

This evaluation includes an environmental product assessment in which all environmental effects from the production process and the in-service and end-of-life phases were weighted, using environmental impact values. The environmental impact values are indexes to express the degree of environmental effects that processes and activities may have, such as transport processes, assembly methods, energy production methods, plastics and metal production methods, and disposal measures.

For a better understanding of the environmental evaluation of a product it may be necessary to illustrate this point briefly by using the aspect of surface varnish as an example. The segment of the frame that is under consideration here has a surface of 0.61 m^2, which must be painted. The environmental impact of the varnish that is used must be weighted with an environmental impact value of 26 per m^2 of the surface to be painted. The mathematical product of these two values is the corresponding environmental impact.

[120] An "ecological balance sheet" is an environmental management technique. Environmental management makes use of a number of specific techniques which permit a simplification of complex problems and which thus contribute to a structured approach to environmental management tasks. See Kamiske et al. (1995), p. 49.

Table 28 shows an extract of this type of ecological impact assessment, as applied to a frame segment produced by differential construction.

Frame Segment / Differential Construction			
Description	Quantity	Eco-Value	Total
Production phase			
Drilling	0.84 kg	0.12	0.10
Surface varnish	0.61 m^2	26	15.86
Transport	0.5 tkm	0.34	0.17
. . .			
Total			81
End-of-life phase			
Recycled aluminum	1 kg	11	-11
In-service phase	47040 tkm	0.81	38102.40
Total			**38172.40**

Table 28: Ecological product assessment of a frame segment with differential construction

This table clearly shows that the environmental impact that an aircraft has is dominated by the environmental effects of the aircraft during the long in-service phase of the aircraft. During the in-service phase, the emphasis must be placed on a reduction of the aircraft weight, as this will be directly expressed in reduced fuel consumption.

Table 29 shows a comparison of the environmental impact of frame segments produced with integral and differential construction.

Phase / Variant	Production	In-service phase 20-30 years	End-of-life phase / Recycling	**Total**
Integral construction	183	27216	76	**27323**
Differential construction	81	38102	11	**38172**

Table 29: Results of an environmental assessment of a product in eco-points

On the basis of the results from table 29 it is clear that from an environmental point of view, the integral construction method leads to better values than a differential construction would. The greater environmental impact of the integral construction method during the production and disposal phases is clearly more than compensated by the reduced weight of the aircraft, and thus the savings that result from the use of less kerosene.

This example shows one possibility of how integrated environmental protection measures can be implemented during the design phase, and how it is possible to reduce costs during the in-service phase in addition to limiting the environmental impact.

It is planned that the results obtained by the Team for an Environmentally Sound Design will in the near future become part of a company directive that will be applicable at all the plants of EADS Airbus Company.

5.3 Complexity in companies – A problem in general

Continuous growth of parts has characterised the trend in numerous companies over the last decade. The general validity of this statement can be demonstrated by the following examples.

A company in the printing machine sector recorded a rise of about 165,000 (approx. 35%) in item numbers for new parts over a period of three years although no new products had been developed in this time[121]. In this connection the annual turnover increased but the return on investment within this period decreased. Between 1980 and 1990 the number of vehicle versions produced and offered by BMW increased by approx. 460%, and this trend is still rising. The item numbers required for extra equipment used in exotic variants in some cases increased by over 40%. These new parts normally have to be available for over fifteen years and increase costs for storage[122]. The front seat of the Audi A6 is available in 4,000 possible options, Porsche's product range contains 700 different door linings, Bosch has 820 wiper blade options in their product range, and for the Audi A4 the consumer can choose between 1,200 different bumper options[123]. Overall item numbers for parts in the automotive sector quadrupled in the nineties. These are only a few examples of the increase in complexity regarding parts and variants in companies. This massive surge in complexity has a detrimental effect on the cost structure in companies. Long-term prospects of success in terms of a competitive strategy, such as cost leadership, suffer lasting damage due to the high growth in complexity within a company.

The following practical examples clarify this problem and are intended to illustrate solutions of how in-company standards can help to reduce complexity and thus ensure an efficient value-added process.

5.3.1 Reasons for and economic consequences of high complexity

The company under observation is a leading European supplier of systems and solutions for in-company logistics. Besides the production of industrial trucks and other equipment for warehousing, its core operative business activities also extend to the machine-leasing sector and technical service. In 2001 the company achieved an annual turnover of € 1.55 billion and an annual surplus of € 39 million.

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[121] Cf. Suttrop (1999), p. 48.

[122] Cf. Ungeheuer (1993).

During the course of reorganisation at the beginning of the nineties, the company standardisation department, which had been responsible for the documentation and the maintenance of parts, was dissolved. This decision was justified by cost-cutting measures. At that point in time the material classification was no longer maintained centrally and modifications were not audited. The classification and assignment of new parts was delegated in a process of decentralisation to numerous employees, mainly designers. This measure leads to a situation in which each manufacturing plant and each production line designated and classified its parts independently. Reconciliation of the parts stock of these departments was just as rare as that between the manufacturing plants. A lack of awareness among many designers as regards the influence of a high growth rate of parts on cost-effectiveness led to the quality of classification sinking considerably. The following actions were mainly responsible for this situation:

1. The description of parts by the designers was often incomplete in terms of the features on which the search for already-used parts was based.
2. The parts information system already contained existing parts that had been designated and classified several times over.
3. New classes had been generated, which exhibited overlapping content.

The function of a parts information system to search for repeat parts was being disabled by this constellation. At the end of this "decentralisation-strategy" the parts information system was almost unusable. This situation is illustrated by an abstract of the structure of the part information shown in figure 30.

new class	old class	number elements	total number
-batteries	45701 battery	749 elements	749 elements
-sealings	22501 chunky	330 elements	
	22502 sealing	646 elements	
	22504 sealing	380 elements	
	22505 sealing	83 elements	
	22506 sealing	139 elements	1578 elements
-electro-technics	22501 protective switch	27 elements	
	22502 fuse; electrical	110 elements	
	22503 fuse accessories	35 elements	
	22601 cable eye	86 elements	
	25602 cable connector	50 elements	
	25603 plug apparatus	402 elements	
	25604 socket	50 elements	
	25605 beam socket	111 elements	
	25606 print plug	104 elements	975 elements

Figure 30: Reorganisation of a parts information system

[123] Cf. Schuh/Müller (1998), p. 37.

During this period there were five classes of seals. Four of them bore the class denomination "sealing". These classes included a varying number of elements for each respective part: the smallest class contained 83 elements, while the largest contained 646. Other classes contained no elements or merely a small number. This absence of conditions to permit a quick and successful search for previously used components, devices and parts in the product range led a number of designers renumber already classified parts, because this action normally required less time under the given conditions than searching for the part concerned the parts information system. In one extreme example, a single part had sixteen different numbers. This uncontrolled growth resulted in an enormous boost in the material master data within this period. From 1990 to 1998 the number of material master data rose from 103,000 to over 326,000. This increase was equivalent to an average annual growth rate of over 15%. Figure 31 below illustrates this trend against the average growth rate for material master data of 5% determined by ISO.

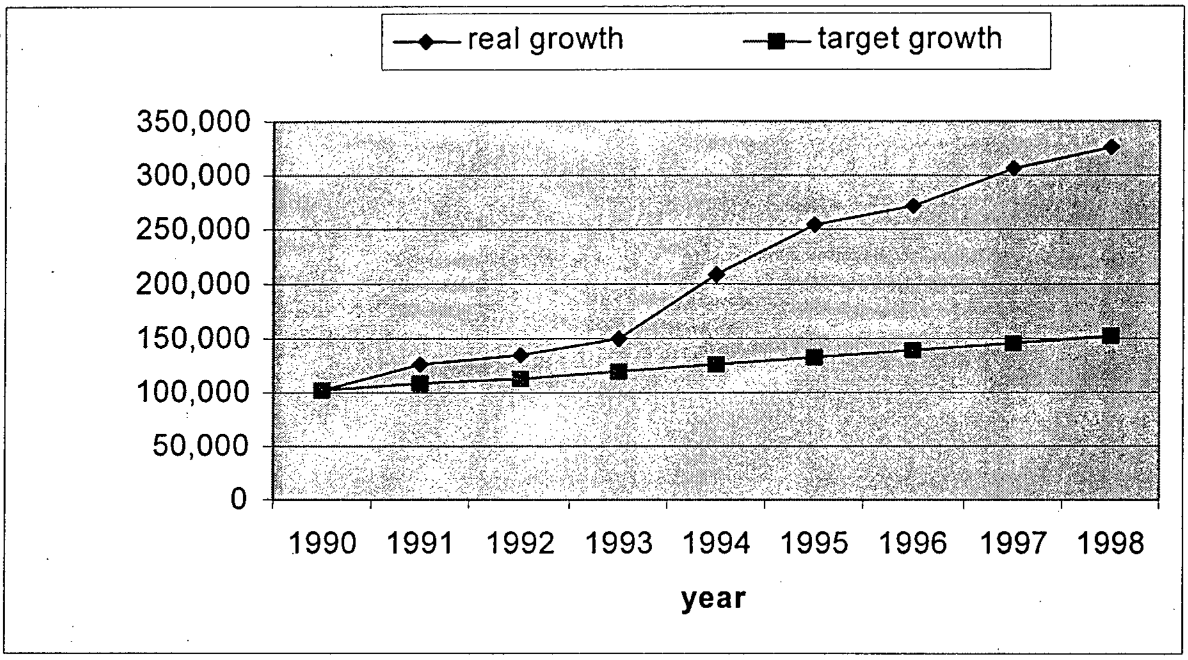


Figure 31: Growth in the number of material master data compared with the ISO rate

The negative effects resulting from this trend become particularly apparently when viewed in terms of the costs incurred by the creation, administration and maintenance of material master data.

Source	Object of analysis	Year	Cost	Mean value for 2002*
Ehrlenspiel	management of bought-out part	1998	€ 1,500 to 2,000	€ 2,047
Steiner	total costs per item number and year	1995	€ 750	€ 987
Bernhard	implementation of a new part in mechanical engineering	1975	€ 500	€ 1,442
Lamatsch	master records costs per part and year	1992	€ 400	€ 592
Pflicht	administration costs for a new part	1988	€ 500	€ 585
Häusele	administration costs per part	1989	€ 1,261	€ 2,100
IGS	average costs for the administration of a part	1992	€ 1,200	€ 1,776
Hichert	creation and maintenance of a part	1986	€ 850	€ 1,592

*Calculated with a annual growth rate of 4%

Figure 32: Administration costs for the implementation of a new part[124]

A detailed view at figure 32 shows that research in this field is relatively rare. This fact is made clear looking at the point of time in which the studies were conducted. The oldest dates were from the year 1975. Beyond it there are some differences regarding the object of analysis. While some authors quantify the costs for the implementation of a new part, others focus on the cost for maintenance or the cost for administration. The relatively great variations in estimated amount, from € 585 to € 2,100 must be due to different approaches in calculating the costs or to different forms of company-specific processes[125]. One frequent deficit in figures quoted is the underlying calculation method is not explained at all or if so, only briefly. Consequently, the approach used to calculate amounts is only comprehensible to a limited extent. Explicitly demonstrating activity-based costing, which calculates the costs incurred by implementing a new part in the affected functional departments, is therefore an important research task within the management of complexity[126].

A comparison of the real growth of material master data in this company and the target growth of 5% against a global weighting regarding the creation of a material master data of € 1,000 yields the following result.

[124] Modified and adopted from Bertram (1999), p. 177f.

[125] In other sources the estimated cost for the intake of a new part are much higher still. For example Briel et al. calculated the costs incurred for the intake of a new part in the construction, production and administration sections as € 6,500.00. Cf. Briel (1983), p. 387f.

[126] The author is going to conduct such an activity-based costing in this company during the second half of this year.

Year	Real growth	"Target growth" of 5%	Real costs in million €	Costs based on 5% growth in million €
1990	103,079	103,079	-----------	-----------
1991	126,073	108,233	22.994	5.154
1992	135,051	113,645	8.978	5.412
1993	150,594	119,327	15.543	5.682
1994	208,324	125,293	57.730	5.966
1995	253,289	131,558	44.965	6.265
1996	270,800	138,136	17.511	6.578
1997	306,965	145,043	36.165	6.907
1998	326,138	152,295	19.173	7.252

Figure 33: Growth of material master data and resulting costs

Figure 33 shows that the costs caused by the high growth rate of material master data are enormous. The calculated difference based on the year 1994, for example, amounts to more than € 50m. However, this amount is too high in terms of the level of acquisition of many firms. These acquisitions have in fact caused the number of material master data to rise, but the costs are lower due to the fact that these data existed already and did not have to be created completely from new but could be transferred to the existing parts information system. Apart from the estimated costs of € 1,000 per part the form of the calculation used there is also a secondary factor that has to be examined critically. This figure concerned is the underlying "target-growth-rate" of 5%[127]. This value comes from a publication dating from the year 1982. The changing conditions of the market, which are characterised by increasing dynamics, mean that this guideline value has to be revised.

Experience from discussions with the management of companies shows that many decision-makers still underestimate the negative effects of high complexity on the level of parts and components. Published data literature is often outdated and the method of calculation is generally not comprehensible. Such facts have reduced the validity of these data, so that it is not possible to create sufficient awareness among the management. This situation shows that a more up-to-date survey of data is required. This applies to both the average costs of a part and for the costs incurred by the intake of a new part into a company.

This task presents a main focus of research for the second half of this year.

[127] Numerous representatives from companies from different industries criticised this value as being too low and unrealistic.

5.3.2 The impact of a differentiation strategy on the production process

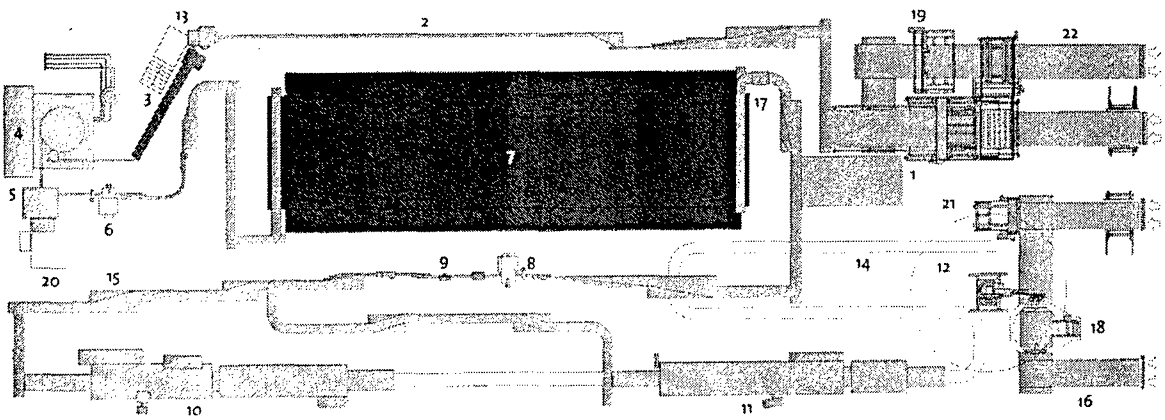
The company considered in the following operates in the beverage industry and also helps to illustrate the increase in costs caused by high complexity. The total turnover of the company came to approximately € 1.2 bn in 2001 with a production volume of 28.3 million hectolitres. Apart from various brands of beer, the product range includes beer-based drinks, soft drinks and mineral waters. In recent years the company's business policy has been characterised by the acquisition of numerous companies from the same industrial sector. As a result of this expansion and due to the continuation of acquired marks, the complexity of products rose significantly. The closedown of locations and production capacities resulted in a wider product range for the remaining production facilities. Within this fiercely contested market segment with declining national sales figures[128] in the main business, the company is trying to develop new markets by adopting a differentiation strategy. Besides product innovation, the differentiation is achieved mainly via novel primary and secondary packages[129]. The achievement of advantages in differentiation is thus bought through a growing complexity in the company. The negative effects of the increased complexity on the value-added process become especially clear in the production sector, as shown by the following examples. Apart from describing the relevant production processes in continuous flow production, the following part contains business data to demonstrate the cost-driving impact of complexity on the value-added process.

Filling

The production process of the company in question focuses on the fabrication of alcoholic beverages and filling these into bottles, cans and casks. Research centred on the filling section. Five machines are employed in this sector of the company. On machines A, B and C the respective goods are filled into bottles. Here, filling machine A is principally used for small quantities, while machines B and C are used for bottling medium and bulk quantities. The capacity of these machines is 60,000 units per hour. Machines D and E fill cans with a 90,000 units, with a capacity per trading unit of 0.33l and 75,000 with a capacity per trading unit of 0.5l. The total number of can sizes that be filled on machines D and E are 250ml, 275ml, 330ml, 500ml and special sizes of 430ml for the British market. In particular, machines D and E operate at full capacity on a three-shift basis.
Because of the different brands in different trading units there has been considerable growth in the complexity of this company. In the bottle filling section there are 28 different crown caps, 68 characteristics of front labels, 120 different rear and neck labels. The lifecycle of these small parts is 1.5 to 2 years on average. There are also 30 different shapes of bottle in

[128] In the nineties the consumption of beer sank in Germany from 142l to 127l per head. This tendency has continued in recent years, albeit to a less marked degree.
[129] An example of innovation in the field of primary packages is the PET plastic bottle and of new secondary packages the cardboard bottle carrier with autonomous panel for 6 beer bottles. This kind of package is preferred by consumers in the United States of America. An illustration of this type of panel can be found at w. A. (1985), p. 63.

the assortment and 15 sorts of beer crate with various dimensions. Thus the filling process and the machines involved have to be set up to match the different trading units, closures and labels with each change in production[130]. The following figure shows the process of filling and the machines involved.



1 pushing device, **2** cable transport, **3** rinsing machine, **4** can filler, **5** can closure, **6** filling level control, **7** pasteurizer, **8** filling level control, **9** Inkjet dating, **10** six packer, **11** tray packer, **12** palletizer, **13** tin separator, **14** trade unit transport, **15** box transport, **16** palette transport, **17** pressure-relief station, **18** palette stretcher, **19** empty palette magazine, **20** shears stroke table, **21** palette magazine, **22** palette transport

Figure 34: The filling process – machines and working steps[131]

The important factors determining the extent of change-overs are the various features of the products involved. Let us look at a relatively simple changeover: a change in the contents while retaining the primary package.

If the products are very similar, only few run-out, change-over, cleaning and starting operations are necessary. This is the case for example if the production process is adjusted from a standard bottle of 0.33l with a standard product to a diet beer in the same standard bottle. The target value in such a situation averages 30 minutes. A more complex change-over, such as the change from a product with added sugar to a sugar free standard product, requires more operations.

Such a changeover requires an exhaustive and hence time-consuming cleaning operation, because the piping has to be rinsed with oxygen-free water. After that the piping is rinsed with bases to eliminate sugar residue and rinsed once more with oxygen-free water. Any oxygen residues are eliminated by pumping through carbon dioxide. This type of changeover needs a target time of 1.5 to 2 hours.

Whereas the previous examples have only considered a changeover of product, a change in the packaging needs extra arrangements. A change in packaging requires adjustment of the filling machine. If the difference in elevation exceeds a height of 1.5 mm, the bottle filling machine has to be adapted to the new elevation[132]. In this case the feed pipes of the filling

[130] This type of change-over might involve a change from a longneck bottle with crown cap to a short-neck bottle with screw closure.

[131] From w.A. (2002), p. 73.

[132] Minor changes in the elevation of the bottles used also demand readjustment of the filling machine, due to the hazard that too much product entering each bottle. From the production viewpoint this wastage can be neglected.

machine have to be manually readjusted or pipes with deviant dimensions have to be installed. Dismantling and reinstallation take one hour. To fulfil the prescribed hygiene standards, this machine has to be continuously cleaned with base and water. This operation needs again 30 minutes.

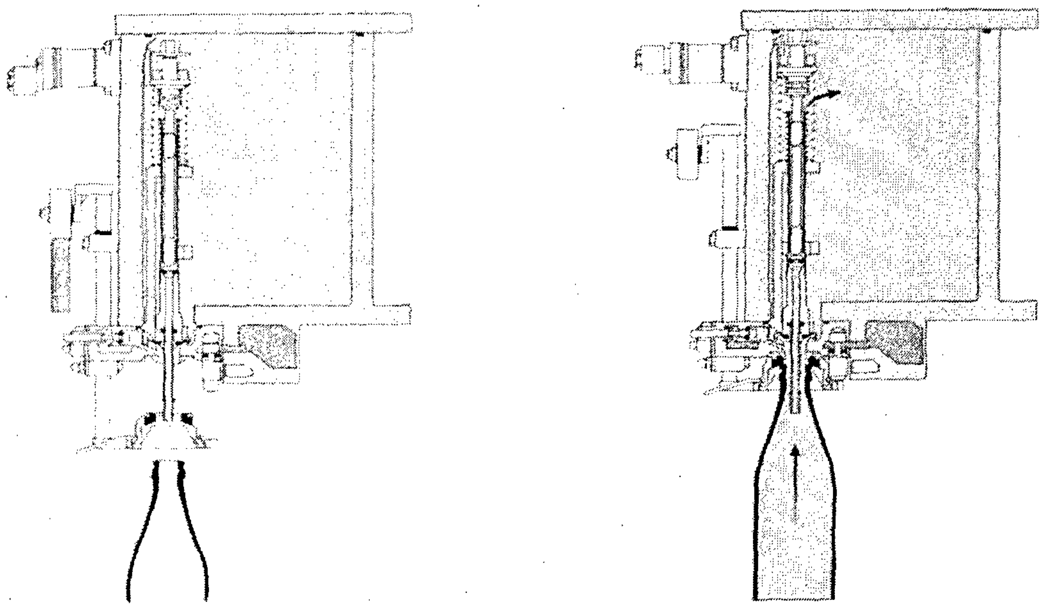


Figure 35: Adjustment and filling phase of a filling machine[133]

Changing the bottles usually involves changing the labels. The changeover of the labelling machine takes place by disassembling and reinstallation of the label-dispensing column. This procedure takes 20 to 25 minutes on average. Depending on the bottles used, the packing machine may also have to be changed. This changeover involves disassembling the vacuum cup unit. The vacuum cup unit has to be adapted to ensure that the bottles are picked up correctly. If this is not the case, alterations and adjustments are necessary while production is running. This considerably hampers the efficiency of the production and filling process. The whole set-up time for this is 45 minutes.

In the case of export the overfilling of bottles could cause negative consequences. For example Great Britain would raise massive retribution taxes, if the filled mass exceed 1ml.

[133] From w.A. (2002), p. 43.

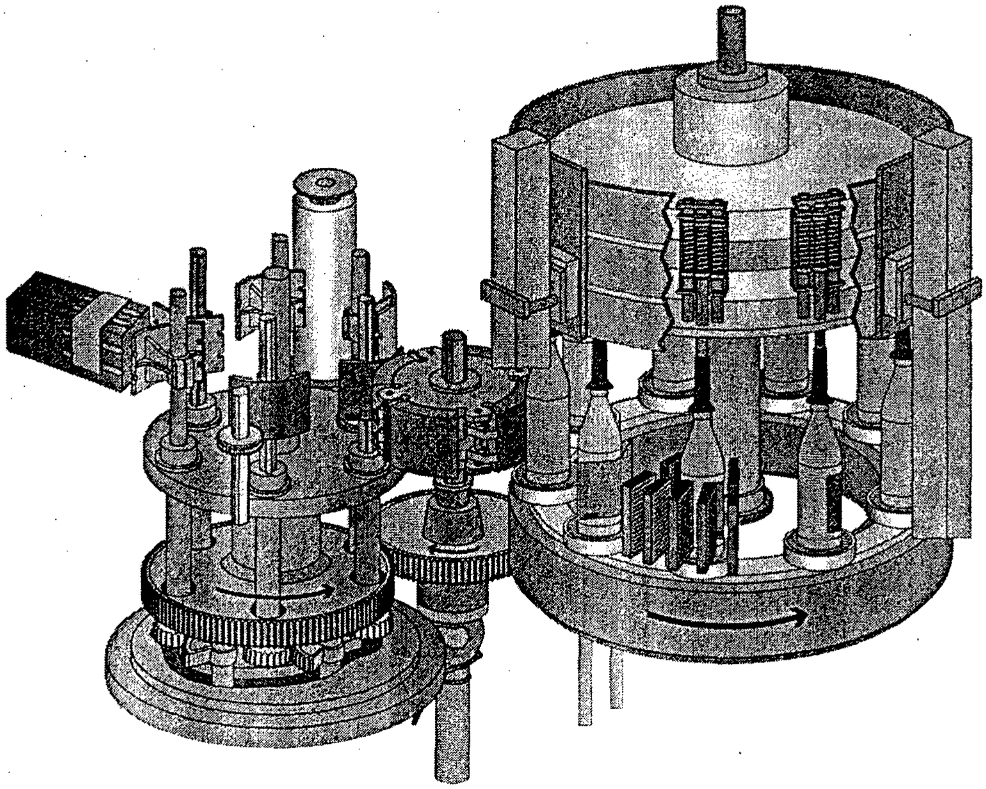


Figure 36: The process of labelling[134]

The operations illustrated here are managed by employees. The number of operations depends on the particular type of changeover. These operations incur expenditure that damages the cost structure in this department. Labour costs between € 1,000 and € 1,600 per hour accrue depending on the extent of the operation to be performed. The resulting loss of production also has to be considered, and with such small margins at such high production rates this is also of great relevance. The high level of complexity that has developed within this company means that several changeovers per day are the norm. Mathematical optimisation methods can be used to reduce the negative impact of this high complexity to a manageable level[135]. These methods enable the production sequence to be selected, thus substantially reducing the costs of changeover. However, in this case the company does not employ mathematical methods of this kind to optimise its sequencing problems. There is obviously considerable scope for improvement in this area, and if complexity continues to increase, steps should be taken to alter the situation.

The complexity of variants displayed also has an influence on the filling capacity of the machines in general. For instance, the capacity of machines D and E decreases when the packaging variant wrap-around, also called the suitcase carton, is used. Production falls from 75,000 units to 50,000 units because the packaging process is significantly more time-consuming than the process used for commercial trays for the domestic German market.

[134] From w.A. (2002), p. 49.
[135] A detailed debate concerning sequence production problems can be found in Müller-Merbach (1970) or Rehwinkel (1978) for example.

When such orders as these are accepted, which increase the complexity of the production process and decrease plant capacity, established sales figures should be available so that above-average profit margins can be set. A lack of knowledge in the field of marketing and distribution regarding the effects of such orders on the production process may otherwise lead to an increase in costs that cannot be fully compensate for by the new order.

An example of how a growth in complexity has been prevented via profitability analysis is given by a customer who wanted products delivered on a so-called "Düsseldorf pallet"[136].

Lack of memory in the automatic palletiser, which turns and stacks the trays and wraps the pallets with plastic foil to stabilise and prevent them from falling over, meant that no additional packaging scheme could be implemented. The reason for this lay in the 26 existing complex transfer options for stacking the trays. These complex transfer options used up all the memory capacity. Accepting this order would have meant replacing or upgrading the computer unit. The costs of this action amounted to € 50,000. In this case the inefficiency that would have resulted from accepting this order was demonstrated by the production department. As consequence, the order was cancelled and the growth in complexity was stopped[137].

The appraisal in this company shows how corporate policy geared towards expansion can increase complexity. This process is intensified in many companies by policies pursued in the fields of marketing and distribution. When the product program is laid down, the production department often does not have enough influence to prevent uneconomical orders from being accepted. One reason for this is no doubt the lack of investigations that demonstrate the negative influence of high complexity on the production process. Extending such investigations to cover with different production structures and processes is therefore another task within this research project.

5.4 The use of standard parts – a means of reducing costs

Approximately 70% of the subsequent manufacturing and material costs are determined during the design phase[138]. Practice shows that findings from business administration are still given too little attention in the design process. A study conducted by EADS Airbus GmbH examined the opportunities for replacing drawings parts by standard parts. The result showed the enormous potential for cost reduction that can be achieved by giving greater consideration to standard parts in the design process. Random sampling showed that on average the cost of

[136] Some customers prefer the "Düsseldorf pallet" compared with the common "euro pallet" because of its dimensions.

[137] Other companies in this industrial sector have been trying for a long time to restrict the grade of complexity to a passable level so that they can produce cost efficiently. For example, the product range of a successful brewery in northern Germany consisted of only four sorts. These are produced in large production batches, so that costly changeovers only seldom occur. Even special wishes from customers concerning the packaging are only accepted after consultation with the production or filling department. This practice has helped to demonstrate the inefficiency of numerous orders, so that they were declined. This information was gathered from a dialogue with an executive employee from the production department of the company concerned.

[138] Cf. Conrad (1998), p. 251.

obtaining standard parts is only 10% of that for drawing parts. A reduction in the number of drawing parts therefore significantly supports the competitive strategy of cost leadership. This fact is illustrated once more in the following figure.

Type of component	Price of drawing part (in €)	Price of standard part (in €)	Ratio
Washer	8.20	0.07	117.1
Bolt	3.22	2.27	1.4
Set screw	26.05	0.57	45.7
Screw	21.70	9.12	2.4
Pivoting bearing	301.02	19.28	15.6
Bush	7.67	2.30	3.3

Figure 37: Prices of standard and drawings parts[139]

Further cost savings are achieved through the different frequencies with which the standard and drawings parts are used. In an airliner the usage ratio of standard to drawings parts is 15:1. This means fewer orders have to be made, which leads to further cost savings. The number of storage places needed and inventory data records is also reduced, which enables further cost savings to be achieved.

The following example is intended to provide supporting evidence for the statements made.

Both designs of a geometrically simple washer, which were recorded in the material management department as both a drawings and standard part, were identical in their geometrical measurements and made of the same material. It would therefore be possible to replace the former by the latter without any restrictions.

The price of the standard part was € 0.05 per unit whereas the drawings part cost € 0.18. Each part had its own object number and occupied a separate storage compartment. Consequently, the price advantage gained by replacing the design part by a standard part is € 0.13 per piece. In addition to the lower purchase price, a substantial cost saving is also derived in warehousing as the number of storage places decreases. The costs for a warehouse place were put at

- approx. € 600 for the set-up and
- approx. € 300 for annual maintenance.

Further cost-reducing effects due to lower reserve stocks, the reduction in ordering transactions and possible price benefits in purchasing due to greater order quantities are ignored in calculations of the savings achieved.

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[139] The data were made available to the department by EADS Airbus GmbH.

Investment accounting provides a formula for calculating the current value of savings.

$$K_0 = E_0 \cdot \frac{(1+w)\cdot\left[(1+i)^n - (1+w)^n\right]}{(i-w)\cdot(1+i)^n}$$

where the variables are

K_0 :	present value of the savings
E_0 :	savings in the first year
w :	growth rate
i :	discount factor
n :	duration of the investment project

Discounting to a current value yields a quantitative comparative figure, which enables a comparison to be made with other investment options for the released capital. The following assumptions were made for the calculation:

- the service life, n, of the component is 20 years, corresponding to the product life span of an aircraft
- the growth factor, w, is set at 3% and assumes a long-term inflation rate of 3%
- an alternative financial investment, I, on the capital market or deployment in other divisions of the company yields 8%

Consequently, savings in administration costs taken over 20 years due to the reduction of a storage place amount to some € 4,500. If an annual requirement of 5,000 items is assumed, the savings in procurement costs amount to € 8,100. The overall saving achieved by the replacement of this part amounts to approximately € 12,600 over a period of 20 years.

In addition to the cost-reducing effect, intensified used of standard parts also supports the competitive strategy of differentiation. Due to the number of potential suppliers, the availability of standard parts is far higher than for drawings parts. The maintenance costs of airliners are thus reduced and greater flexibility is achieved during the maintenance procedure. This increases the product benefits for the operator. The use of standard parts must, however, not lead to technically inferior products as this would mean that the price to achieve the cost savings had been an excessive loss in differentiation.

At EADS Airbus GmbH the findings presented are reflected in a new operating procedure for designers. According to this, a designer wanting to use a drawings part has to file a request to the standardisation department. Using the technical data, the standardisation department investigates whether this part might not be replaceable by a standard part. This process is generally completed within 24 hours.

The preceding examples were supposed to illustrate how the adequate use of in-company standardisation can improve the competitive position of a company. An overview of the relevance in-company standards in the sector of mechanical engineering presently have give the shown results from a company inquiry in the next chapter.

Summary chapter 5

In this chapter some examples from industry are given to clarify the economic significance of in-company standards. It first describes preventive environmental protection measures and the beneficial effects that can be achieved for companies through an effective environmental management program. In this connection the advantages of so called EOP-Technologies were shown. Following on from this, several examples of the beneficial effects that can be achieved for companies through an effective environmental management program were given.
The focus then shifts to the reasons for high complexity in companies and its influence on cost structure. In this case three reasons (actions) were mainly responsible for the extreme high growth rate for material master data:

1. The description of parts by the designers was often incomplete in terms of the features on which the search for already-used parts was based.
2. The parts information system already contained existing parts that had been designated and classified several times over.
3. New classes had been generated, which exhibited overlapping content.

This actions lead to an average annual growth rate for material master data of over 15%. The costs caused by the high growth rate of material master data were enormous high. Furthermore the causal connection between a differentiation strategy and the variety of parts were analysed by an example of a brewery. Here we focused on the impact of an increased variety of parts on the production process.
The chapter ends with an example of the cost-reducing effect derived from the extensive use of standard parts. The result showed the enormous potential for cost reduction that can be achieved by giving greater consideration to standard parts in the design process. In this case the average costs of standard parts were only 10% of that for drawing parts.

6 Research results from a company inquiry: complexity management and in-company standardisation

6.1 Objectives of the company inquiry

An objective of the company inquiry was to achieve current information concerning the importance of in-company standardisation measures in the field of complexity management in small and medium-sized enterprises. A focus aims at the question to what extent company and product specific criteria have an impact on the application and the success of in-company standards. Furthermore the achievement of current information regarding part growing, measured by the growth of material master data, is of high importance. For this issue 524 companies in Germany and the Netherlands have been written down. Most written down companies are in the industrial sector of mechanical engineering. The other companies are mostly active in the sectors of electrical engineering, automotive engineering, shipbuilding and aerospace industry.

6.2 Extent of company inquiry and rate of return

The written down companies are allocated to several industrial sectors:

Automotive engineering	33
Mechanical engineering	289
Electrical engineering	143
Aerospace industry	34
Shipbuilding industry	25

From 524 written companies 58 sent back a filled out questionnaire. Hereof only 53 questionnaires came in the appraisal, because five questionnaires merely filled out incomplete. These 53 questionnaires are allocated concerning the different branches as follows:

		Rate of return in percent
Automotive engineering	2	6.06%
Mechanical engineering	34	11.76%
Electrical engineering	9	6.29%
Aerospace industry	1	2.94%
Shipbuilding industry	1	4.00%
Others	6	

Altogether the unadjusted rate of return averages 11.07% (58) respectively adjusted 10.11% (53). It is noticeable that the rate of return in the sector of mechanical engineering is with 11.76% clearly above the other rates which are all lower than 6.3%. The six questionnaires in the category others have a certain impact on this result.

With over 55% the 289 written down companies in the sector of mechanical engineering represent the absolute majority in comparison with the companies in the remaining branches. In consideration of the relative high rate of return of 11.76% an isolated analysis of the mechanical engineering is made, because only in this sector the number of questionnaires is sufficient to make profound statements regarding a single industrial branch.

Company characteristics

		Occurrence	percentage	Valid percentage	Cumulative percentage
Valid	€ 0.1-10m	16	47,1	47,1	47,1
	€ 10.1-50m	7	20,6	20,6	67,6
	€ 50.1-250m	7	20,6	20,6	88,2
	higher than € 250.1m	4	11,8	11,8	100,0
	Total	34	100,0	100,0	

Figure 38: Amount of turnover

23 of the 34 interviewed companies can be dedicated to the group of small and medium-sized enterprises[140]. The company distribution on four groups of turnover is shown in the following figure.

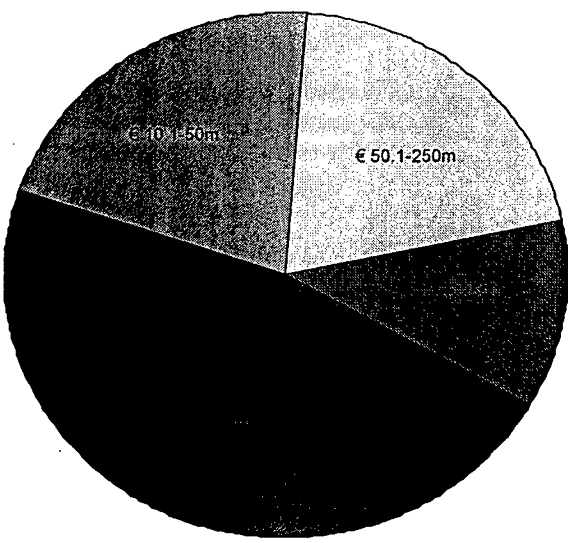

Figure 39: Turnover of 34 companies in the sector of mechanical engineering

Furthermore it has been of high interest, to what extent the enterprise size, measured by turnover, has an impact on the existence of a standardisation department[141]. An exhaustive

[140] In this connection as selection criterion a definition of the IfM (Institut für Mittelstandsforschung) has been chosen. The turnover maximum for small and medium-sized enterprises is here by € 51.13 million.

[141] In several cases the question regarding the existence of a standardisation department has been approved, whereby in these departments are only one or two employees working. Hence in this connection the circumscription "employee with the focus on standardisation" has been chosen.

consideration of figure 40 shows that all companies with an annual turnover above € 51.1 million have at least one employee with the working focus on standardisation. Even in three of seven companies with an annual turnover between € 10.1 and 51 million are employees with a focus on standardisation. This relation is far more negative in companies with an annual turnover under € 10 million. Here only two of sixteen companies have employees who work mainly in the field of standardisation. Due to the low number of employees in small companies the handling of tasks in the field of standardisation is decentralised and done by different employees with other major responsibilities in general. A feature of big companies is the higher degree of specialisation connected with clear scopes of competence and duties. This fact is certainly one reason which facilitates a central handling of questions concerning standardisation.

How far these relations and the data in figure 40 allow profound conclusions regarding the reality in companies should be scrutinised critically, because an employee whose working focus is in the field of standardisation can complete the den questionnaire considerable faster than a colleague who is foreign to the subject. Against this background it can be assumed that the here documented likelihoods for the existence of a standardisation department in companies is overall too high.

			Standardisation department		
			no	yes	Total
Turnover group	€ 0.1-10m	Number	14	2	16
		Standardisation department	77,8%	12,5%	47,1%
	€ 10.1-50m	Number	4	3	7
		Standardisation department	22,2%	18,8%	20,6%
	€ 50.1-250m	Number	0	7	7
		Standardisation department	,0%	43,8%	20,6%
	higher than € 250,1m	Number	0	4	4
		Standardisation department	,0%	25,0%	11,8%
Total		Number	18	16	34
		Standardisation department	100,0%	100,0%	100,0%

Figure 40: Cross-classified table turnover / existence of a standardisation department

After giving an overview concerning the structure of interviewed companies by the criteria turnover existence of a standardisation department, the following section deals with the impact of company and in particular product specific features on in-company standards.

6.3 The impact of company and in particular product specific features on in-company standards

The price of sale

One aim of the company inquiry targets on the appraisal to what extent company- and product-specific features can be useful indicators to estimate the effect of company standards on the business success. In this chapter the research results are diagrammed in cross-classified tables, whereby in each case a product specific feature (price of sale, expected useful life or innovation loops) is compared with an in-company standard like (size range or unit assembly systems, modularisation, platform concepts or the amplified use of identical and repeat parts). In an ideal case the cross-classified tables give results which, comparable to a benchmarking process, allow a first choice of in-company standards with a positive impact on the competitiveness of companies.

Anzahl

		Importance of complexity reduction						
		not any	very low	pretty low	pretty high	very high	extreme high	Total
Average sales price	€ 10-100	0	0	1	2	0	0	3
	€ 100-1.000	0	0	1	0	0	0	1
	€ 1.000-10.000	1	1	2	1	3	0	8
	€ 10.000-100.000	1	0	5	2	1	1	10
	higher	2	0	0	6	3	1	12
Total		4	1	9	11	7	2	34

Figure 41: Importance of complexity reduction / price of sale

The four companies, whose products have a selling price below € 1,000, evaluate the meaning of complexity reduction relative neutral. The other companies, who pay no attention to the reduction of complexity, produce in the first line especial to customer orders and preferences. In fact these products contain numerous parts and assembly groups, by what one success criterion is given. But high work piece quantities of a product are here more the exception, whereby the cost reducing effect of the complexity reduction (management) is understated. The products with a selling price below € 1,000 are produced in high work piece quantities, but the absence of technical complexity gives apparently not enough starting points for an efficient reduction of complexity. Such products are for example abrasives or milling heads.
In general the meaning of complexity management is most significant by products with a selling price over € 100,000.

Anzahl

		Importance of size range systems						
		not any	very low	pretty low	pretty high	very high	extreme high	Total
Average sales price	€ 10-100	0	0	1	2	0	0	3
	€ 100-1.000	0	0	0	1	0	0	1
	€ 1.000-10.000	0	1	1	2	3	1	8
	€ 10.000-100.000	0	0	3	2	4	1	10
	higher	1	0	1	4	4	2	12
Total		1	1	6	11	11	4	34

Figure 42: Importance of size range systems / price of selling

In 32 of 34 companies size range systems have at least a pretty low meaning. The highest importance of size range systems can be attested to companies with a selling price for a product above € 10,000. So the in common high acceptance is growing with the selling price. The selling price again is an indicator for a high product complexity.

Anzahl

		Importance of modularisation						
		not any	very low	pretty low	pretty high	very high	extreme high	Total
Average sales price	€ 10-100	0	0	1	2	0	0	3
	€ 100-1.000	0	0	0	0	0	1	1
	€ 1.000-10.000	0	1	2	1	3	1	8
	€ 10.000-100.000	1	0	1	4	4	0	10
	higher	0	0	1	3	5	3	12
Total		1	1	5	10	12	5	34

Figure 43: Importance of modularisation / price of selling

Looking at the relation between modularisation and selling price it comes out that the research results are comparable with size range system. One advantage of products which have a modular structure is the opportunity to substitute a module with a special function by a module with the same or another function. Through this the scope and the length of use is expanded. This advantage is rising with the purchase cost respectively selling price naturally. This circumstance is affirmed by the research results.

Anzahl

		Importance of unit assembly systems					
		very low	pretty low	pretty high	very high	extreme high	Total
Average sales price	€ 10-100	0	1	2	0	0	3
	€ 100-1.000	0	0	0	0	1	1
	€ 1.000-10.000	1	1	2	3	1	8
	€ 10.000-100.000	0	2	4	4	0	10
	higher	0	1	3	4	4	12
Total		1	5	11	11	6	34

Figure 44: Importance of unit assembly systems / price of selling

In the technical literature often there is no explicit differentiation between the terms modularisation and unit assembly systems, though existing several clearly varieties[142]. The research results reflect this aspect, cause in numerous questionnaires the given information have been identically concerning the meaning of modularisation and unit assembly systems. The results and their interpretation are though comparable to modularisation.

Anzahl

		Importance of platform concepts						
		not any	very low	pretty low	pretty high	very high	extreme high	Total
Average sales price	€ 10-100	2	0	1	0	0	0	3
	€ 100-1.000	0	0	0	1	0	0	1
	€ 1.000-10.000	0	2	2	2	2	0	8
	€ 10.000-100.000	1	2	3	2	1	1	10
	higher	2	6	1	0	2	1	12
Total		5	10	7	5	5	2	34

Figure 45: Importance of platform concept / price of selling

The meaning of platform concepts is clearly below the meaning of complexity management. One reason for this for sure is the specific demand of a platform concept on the product features. These features are among other things recurring functions or similar dimensions (automobiles or washing machines) for instance. But if these requirements are fulfilled, then the platform concept allows the production of many variants under comparable low efforts.

Anzahl

		Search for identical and repeat parts					
		very low	pretty low	pretty high	very high	extreme high	Total
Average sales price	€ 10-100	1	0	1	1	0	3
	€ 100-1.000	0	0	1	0	0	1
	€ 1.000-10.000	0	2	3	2	1	8
	€ 10.000-100.000	0	1	5	4	0	10
	higher	0	2	3	6	1	12
Total		1	5	13	13	2	34

Figure 46: Search of identical and repeat parts / price of selling

In comparison with the foregoing discussed in-company standards, internal arrangements to force the use of identical and repeat parts can be implemented simply. Also the relative week influence of company and product specific features on the cost reducing effect of this

[142] In a unit assembly system, the interfaces between units can be such that they are connected permanently. Modules, however, are characterised by clearly defined interfaces between the units. The interfaces between individual modules are aligned with the interface of the basic element while in a unit assembly system, on the other hand, the compatibility of the interfaces between the respective add-on elements is crucial. This difference is also reflected in the relations between the building blocks or modules. In a modular design there should be only a minimum of relations between the individual modules. In their elementary relations (that is, their internal structures), the relations between modules are more pronounced. In the unit assembly system, one very important

arrangement is a reason for the overall high acceptance. The statements concerning the meaning of the use of identical and repeat parts are preponderant (26 of 34) between pretty and very high. This circumstance can be seen as a signal that in most companies the use of identical and repeat parts is already the status quo.

Expected useful life

The expected useful life is in comparison with the price of sale or the innovation loops a pretty fuzzy criterion, because companies have only a week influence on the useful life of their products.

Anzahl

		Importance of complexity reduction						
		not any	very low	pretty low	pretty high	very high	extreme high	Total
Average expected useful life	1-12 months	0	0	0	1	0	0	1
	1-5 years	0	0	2	1	0	0	3
	5-10 years	2	0	4	3	0	0	9
	10-15 years	0	0	1	3	3	0	7
	15-25 years	1	0	2	3	2	2	10
	higher	1	1	0	0	1	0	3
Total		4	1	9	11	6	2	33

Figure 47: Importance of complexity reduction / expected useful life

Figure 47 shows that only companies consider the meaning of complexity reduction very or extreme high, whose products have an expected useful life of ten years or longer.

Anzahl

		Importance of size range systems						
		not any	very low	pretty low	pretty high	very high	extreme high	Total
Average expected useful life	1-12 months	0	0	0	1	0	0	1
	1-5 years	0	0	2	1	0	0	3
	5-10 years	0	1	2	3	2	1	9
	10-15 years	0	0	0	1	4	2	7
	15-25 years	1	0	2	3	3	1	10
	higher	0	0	0	2	1	0	3
Total		1	1	6	11	10	4	33

Figure 48: Importance of size range systems / expected useful life

Looking at the research results, concrete statements to what extent a certain expected average useful life has a positive impact on the effect of size range systems, are only possible in a conditional way. It comes out that products with an average expected useful life of 10 to 15 years have the highest meaning. Another important point is that the best appraisal of products with an expected useful life of 1 to 5 years is at pretty high.

objective is to reduce the variety of parts; in modularisation, an important objective is to reduce the complexity of the system.

Anzahl

		Importance of modularisation						
		not any	very low	pretty low	pretty high	very high	extreme high	Total
Average expected useful life	1-12 months	0	0	1	0	0	0	1
	1-5 years	0	0	1	1	0	1	3
	5-10 years	1	0	2	2	2	2	9
	10-15 years	0	0	0	2	4	1	7
	15-25 years	0	0	1	4	4	1	10
	higher	0	1	0	1	1	0	3
Total		1	1	5	10	11	5	33

Figure 49: Importance of modularisation / expected useful life

A look at the research results shows that the optimal expected useful life concerning modularisation is between 10 and 15 years. Also the ranking in the two adjacent categories is on a relative high level. A little bit astonishing is the diminishing popularity, which takes up with products with a longer expected useful life then 25 years, although the benefit of modularisation is normally rising with an increase of the expected useful life.

Anzahl

		Importance of unit assembly systems					
		very low	pretty low	pretty high	very high	extreme high	Total
Average expected useful life	1-12 months	0	1	0	0	0	1
	1-5 years	0	1	1	0	1	3
	5-10 years	0	2	3	1	3	9
	10-15 years	0	0	1	5	1	7
	15-25 years	0	1	5	3	1	10
	higher	1	0	1	1	0	3
Total		1	5	11	10	6	33

Figure 50: Importance of unit assembly systems / expected useful life

The results and the resultant derived statements are comparable to the statements concerning modularisation.

Anzahl

		Importance of platform concepts						
		not any	very low	pretty low	pretty high	very high	extreme high	Total
Average expected useful life	1-12 months	1	0	0	0	0	0	1
	1-5 years	1	1	1	0	0	0	3
	5-10 years	0	3	2	3	1	0	9
	10-15 years	0	0	2	2	3	0	7
	15-25 years	3	3	2	0	0	2	10
	higher	0	3	0	0	0	0	3
Total		5	10	7	5	4	2	33

Figure 51: Importance of the platform concept / expected useful life

Merely products with an expected useful life between 10 and 15 years have according to the companies a more positive meaning. In the category of products with an expected useful life up to five years are only negative ratings.

Anzahl

		Search for identical and repeat parts					
		very low	pretty low	pretty high	very high	extreme high	Total
Average expected useful life	1-12 months	1	0	0	0	0	1
	1-5 years	0	1	1	1	0	3
	5-10 years	0	1	6	2	0	9
	10-15 years	0	0	2	4	1	7
	15-25 years	0	1	4	4	1	10
	higher	0	2	0	1	0	3
Total		1	5	13	12	2	33

Figure 52: Searching of identical and repeat parts / expected useful life

In contrast to the criterion „sales price", there is a clear positive vote starting from an expected useful life above five years. The biggest popularity gain once more products with an expected useful life between 10 and 15 years. Also in the category of 15 and 25 years the meaning is relative high.

Innovation loops

Anzahl

		Importance of complexity reduction						
		not any	very low	pretty low	pretty high	very high	extreme high	Total
Innovation loop	1-2 years	0	0	2	2	0	0	4
	2-4 years	1	0	2	3	1	0	7
	4-6 years	0	0	3	2	2	0	7
	6-8 years	1	0	0	2	1	0	4
	8-10 years	1	1	0	0	1	1	4
	over 10 years	1	0	2	2	1	1	7
Total		4	1	9	11	6	2	33

Figure 53: Importance of complexity reduction / innovation loops

Looking at the present figure there is no consistent tendency remarkable to what extent the length of innovation loops has an impact on the meaning of complexity reduction.

Anzahl

		Importance of size range systems						
		not any	very low	pretty low	pretty high	very high	extreme high	Total
Innovation loop	1-2 years	0	0	2	1	1	0	4
	2-4 years	0	1	0	3	1	2	7
	4-6 years	0	0	0	2	4	1	7
	6-8 years	1	0	0	1	1	1	4
	8-10 years	0	0	1	2	1	0	4
	over 10 years	0	0	3	2	2	0	7
Total		1	1	6	11	10	4	33

Figure 54: Importance of size range systems / innovation loops

The clear preference here is at products with innovation loops between 2 and 4 respectively 4 and 6 years. It seems that the advantage of a reduced construction work is an important point for companies and in particular products with innovation loops between 2 and 6 years have apparently the best characteristics therefore. Products with innovation loops between 1 and 2 years have not such high meaning by far. This phenomenon is possibly founded in fundamental technological changes which call for a complete new construction.

Anzahl

		Importance of modularisation						Total
		not any	very low	pretty low	pretty high	very high	extreme high	
innovation loop	1-2 years	0	0	1	2	1	0	4
	2-4 years	0	0	2	1	1	3	7
	4-6 years	0	0	0	0	5	2	7
	6-8 years	0	0	1	2	1	0	4
	8-10 years	0	1	0	3	0	0	4
	over 10 years	1	0	1	2	3	0	7
Total		1	1	5	10	11	5	33

Figure 55: Importance of modularisation / innovation loops

Noticeable is the exceedingly high popularity of products with innovation loops between 4 and 6 years. All companies in this category assess the importance of modularisation very or even extreme high. Also products with innovation loops between 2-4 years get a clear positive ranking.

Anzahl

		Importance of unit assembly systems					Total
		very low	pretty low	pretty high	very high	extreme high	
innovation loop	1-2 years	0	1	2	0	1	4
	2-4 years	0	0	3	1	3	7
	4-6 years	0	0	0	5	2	7
	6-8 years	0	1	1	2	0	4
	8-10 years	1	0	3	0	0	4
	over 10 years	0	3	2	2	0	7
Total		1	5	11	10	6	33

Figure 56: Importance of unit assembly systems / innovation loops

The results are comparable to the statements concerning modularisation.

Anzahl

		Importance of platform concepts						Total
		not any	very low	pretty low	pretty high	very high	extreme high	
innovation loop	1-2 years	1	0	2	0	1	0	4
	2-4 years	0	3	2	1	1	0	7
	4-6 years	1	0	1	3	1	1	7
	6-8 years	0	2	0	1	1	0	4
	8-10 years	1	2	1	0	0	0	4
	over 10 years	2	3	1	0	0	1	7
Total		5	10	7	5	4	2	33

Figure 57: Importance of the platform concept / innovation loops

A positive ranking is only identifiable in the category with product innovation loops between 4 and 6 years. In the category with innovation loops between 8 and 10 years and longer only one of eleven rankings has a positive character. After such a long period the technical features of a platform do not correspond to the market requirements apparently.

Anzahl

		Search for identical and repeat parts					Total
		very low	pretty low	pretty high	very high	extreme high	
Innovation loop	1-2 years	0	1	1	2	0	4
	2-4 years	0	0	5	2	0	7
	4-6 years	0	0	2	3	2	7
	6-8 years	0	1	1	2	0	4
	8-10 years	0	2	1	1	0	4
	over 10 years	1	1	3	2	0	7
Total		1	5	13	12	2	33

Figure 58: Searching of identical and repeat parts / innovation loops

The most positive vote is going once more to products with innovation loops between 4 and 6 years. Including innovation up to 8 years the rankings are predominantly positive. Afterwards the meaning of an increased use of identical and repeat parts declines. This circumstance is comprehensible, because the occurring negative effect on the cost structure of the value-added process is lower, if the innovation loops are comparatively long.

6.4 Appraisal of the weighted research results

The following three charts show the research results in a transformed way. In detail the statements have been weighted with the following values:
(no importance = -5, very low i. = -3, pretty low i. = -1, pretty high i. = 1, very high i. = 3 and extreme high i. = 5). After weighting the values have been added and divided by the number of statements per category. The evaluated key data are located in an interval of [-5, +5] and are indicated in each cell by the first value, while the second value indicates the number of statements. This new results are now discussed under modified standpoints.

Innovation loops

	Complexity reduction	Size range systems	Unit assembly systems	Modul-arisation	Platform concept	Identical and repeat parts
1-2 years	0.0 / 4	0.5 / 4	1.5 / 4	1.0 / 4	-1.0 / 4	1.5 / 4
2-4 years	-0.14 / 7	2.29 / 7	3.00 / 7	2.43 / 7	-1.0 / 7	1.57 / 7
4-6 years	0.71 / 7	2.71 / 7	3.57 / 7	3.57 / 7	0.71 / 7	3.00 / 7
6-8 years	0.0 / 4	1.0 / 4	1.5 / 4	1.0 / 4	-0.5 / 4	1.5 / 4
8-10 years	0.0 / 4	0.5 / 4	0.0 / 4	0.0 / 4	-3.0 / 4	0.5 / 4
over 10 years	0.43 / 7	0.71 / 7	0.71 / 7	0.71 / 7	-2.14 / 7	0.71 / 7

Figure 59: In-company standards / innovation loops

Complexity reduction

It can be said generally that complexity reduction respectively complexity management has in comparison to special kinds of in-company standardisation a lower meaning. Several reasons are responsible for this phenomenon.

On the one hand a lot of decision-makers noticed the negative impact of an excessive high complexity on the cost structure no more than in the recent time. In contrast to the researched in-company standards, which play a major role in many companies since decades, complexity management is of a small importance. Beside this historic component another reason can be seen in the time and cost expenditure implementing a complexity management, because the structure and organisation of the value-added process have to be arranged. To the measures, which affect a sustainable reduction of company complexity, all in-company standards can be mentioned like the platform concept or the use of identical and repeat parts. Such measures are only single components of a comprehensive complexity management, so that single in-company standards can have a high meaning inside the corporate policy, but there has not to be a comprehensive concept to reduce complexity.

Beside the relative small importance of complexity management for companies another point is that the feature „innovation loop“ gives no clues to make concrete statements concerning the benefit of a sustainable reduction of complexity at all. Therefore the six values in the interval [-0.14, 0.71] are too similar.

Size range systems

The values in the category „size range systems" are all positive. The significant highest popularity have products with innovation loops between 2 and 4 years (2.29) and even more at products with innovation loops between 4 and 6 (2.71). This result appears feasible because an important point of size range systems is the uncomplicated and cost-efficient construction of versions with different performance features using similarity laws. The shorter the innovation loops the more frequent this positive feature of size range systems appearance. In this connection the low value of 0.5 in the category 1 and 2 years has to be questioned critically. A prominent characteristic of products with such short innovation loops is the fact that the quality of primary product features decreases rapidly with the technical progress and the use of innovational solutions (differentiation advantage) is more important as a fast and cheap construction (cost advantage).

Unit assembly systems

Overall the companies attach most importance to unit assembly systems of any six in-company standards. Once more the highest values are in the category of products with innovation loops between 2 and 4 or 4 and 6 years.

Modularisation

The research results are similar to unit assembly systems again.

Platform concept
The meaning of platform concepts is only in few companies high. According to this the calculated key data are negative mostly. Only products with an innovation loop between 4 and 6 years have a positive value of 0.71. The importance of platform concepts for products with innovation loops above 8 years is low. This result is comprehensible in respect of the fact that the use of platforms determines numerous technical product features. The technical characteristics of products, which base on a ten year old platform for example, would hardly fulfil the market requirements. Products, which base on platforms, should have the following features in general: The technical solutions in a platform contained should be well-engineered. The existence of fundamental new technical solutions regarding specific functions should appearance rarely. Furthermore as much as possible variants with identical primary product features should build up on a platform. Automobiles or washing machines have these attributes while in the sector of mechanical engineering and in particular in producing special machines such features are rather seldom. Against this background of this the rather low importance of platform concepts in this sector is comprehensible.

Identical and repeat parts
The amplified use of identical and repeat parts has been estimated in all categories positively. Except the very high value of 3.00 for products with an innovation loop of 4 and 6 years the statements are relative well-balanced, whereby the meaning in the case of innovation loops above 8 years is decreasing slightly. In comparison to other in-company standards the amplified use of identical and repeat parts is relative easy to do. Even the small influence of company and product specific features on the benefit of this method certainly has a share in the general acceptance and popularity.

Expected useful life

	Complexity reduction	Size range systems	Unit assembly systems	Modul-arisation	Platform concept	Identical and repeat parts
0-1 year	1.0 / 1	1.0 / 1	-1.0 / 1	-1.0 / 1	-5.0 / 1	-3.0 / 1
1-5 years	-0.33 / 3	-0.33 / 3	1.67 / 3	1.67 / 3	-3.0 / 3	1.0 / 3
5-10 years	-1.22 / 9	1.0 / 9	2.11 / 9	1.22 / 9	-0.55 / 9	1.22 / 9
10-15 years	1.57 / 7	3.29 / 7	3.0 / 7	2.71 / 7	1.29 / 7	2.71 / 7
15-25 years	1.2 / 10	1.0 / 10	1.8 / 10	2.0 / 10	-1.6 / 10	2.0 / 10
higher	-1.67 / 3	1.67 / 3	0.33 / 3	1.0 / 3	-3 / 3	0.33 / 3

Figure 60: In-company standards / expected useful life

How figure 60 shows, the main unit in the category 0-1 year is only one element. So the key data in this category allow no conclusions concerning companies and products with similar expected useful life. Therefore in the following consideration this category will be unconsidered.

Complexity reduction
Overall all data are in a narrow interval of [-1.67, 1.57] and are near to a neutral rating. Only products with an expected useful life between 10 and 15 as well as 15 and 25 years have a clear positive ranking.

Size range systems
Except the category of 1 to 5 years all data are positive. Amazing high is the value of 3.29 in the category of products with an expected useful life between 10 and 15 years. Even the great distance to both neighbour categories of 2.29 points was not predictable in that way.

Unit assembly systems
Even the estimation of the benefit of unit assembly systems is at highest in the category with an expected useful life between 10 and 15 years. But the fluctuations to the adjacent categories are less high so that products with an expected useful life between overall have pretty good characteristics, if they are designed as unit assembly system.

Modularisation
The highest value with 2.71 is once more in the category of products with an expected useful life between 10 and 15 years. In contrast to unit assembly systems the calculated data concerning modularisation are in a relative narrow interval of [1.0, 2.71] and hence on a high level. From there the development and construction of modular products has on the part of companies a high meaning, whereby the criterion "expected useful life" has a more under part role.

Platform concept
Except for products with an expected useful life between 10 and 15 years all key data have a negative algebraic sign. For products with an expected useful life under 5 years the platform concept has nearly no meaning. In the field between 5 and 10 years the calculated data are slight negative, so that here are some products, which base on a platform.

Identical and repeat parts
The importance of an increased use of identical and repeat parts is once more the highest in the category between 10 and 15 years. The value of 2.0 in the category 15 to 25 years is clearly higher than in the category 5 to 10 or 1 to 5 years. An argument for this tendency is surely that the stockage time is growing with the expected useful life. By products with a long expected useful life therefore the negative impact of a high part complexity on the cost structure is longer.

Selling price

	Complexity reduction	Size range systems	Unit assembly systems	Modul-arisation	Platform concept	Identical and repeat parts
€ 1-10	0.0 / 0	0.0 / 0	0,0 / 0	0.0 / 0	0.0 / 0	0.0 / 0
€ 10-100	0.33 / 3	0.33 / 3	0.33 / 3	0.33 / 3	-3.67 / 3	0.33 / 3
€ 100-1k	-1.0 / 1	1.0 / 1	5.0 / 1	5.0 / 1	1.0 / 1	1.0 / 1
€ 1k-10k	0.0 / 8	1.5 / 8	1.25 / 8	1.25 / 8	0.0 / 8	1.5 / 8
€ 10k-100k	0.0 / 10	1.6 / 10	1.4 / 10	1.0 / 10	-0.4 / 10	1.6 / 10
higher	0.83 / 12	1.67 / 12	2.83 / 12	2.67 / 12	-1.5 / 12	2.0 / 12

Figure 61: In-company standards / selling price

Figure 61 shows that only four companies are in the first three categories. The remaining 30 companies produce goods with a selling price over € 1,000. This extreme dispersal is respected by focusing on the three categories with selling prices over € 1,000.

Complexity reduction
In the first two categories the key data have exactly a neutral value. The value of products with a selling price over € 100,000 is slightly positive. But in which way this fact is sufficient to see herein already a tendency to expensive products can not clarified clearly.

Size range systems
The given statements regarding the importance of size range systems are in the three considered categories nearly identical and are situated in an interval of [1.5, 1.67]. Hence it can be said that the selling price is not a suitable criterion to make concrete statements concerning the advantage of size range systems. But in general size range systems have a quite high importance, if the selling price is over € 1,000.

Unit assembly systems
The importance of unit assembly systems is clear the highest for products with a selling price over € 100,000. This calculated value transcends the both other values more than twice and is with 2.83 the most positive vote. In this context the selling respectively buying price in connection with the possibility to change single modules plays an important role.

Modularisation
The made statements to unit assembly systems even count for modularisation.

Platform concept
Products, which have a high suitability regarding platform concepts, are more middle-priced. Especially for products with a selling price over € 100,000 the importance of platform concepts is decreasing. One kind of these products are special machines. The structural specifications by a platform are here often too restrictive; because the position of primary functions could be differ depending on customer requests in opposite to cars for instance.

Identical and repeat parts

The calculated data regarding the meaning of an amplified use of identical and repeat parts are in a narrow interval between [1.5, 2.0] and hence continuous on a high level. Hereby the importance of this measure is rising with an increase of the selling price.

6.5 Current data concerning part growing in companies

Another objective of this company inquiry was in the winning of current information concerning the average part growing in companies. For this companies have been asked for making comprehensive statements in a given schedule regarding the changes of their master data. In this connection the period between 1992 and 2001 was of interest. Overall five companies were able respectively ready to give the asked information. Measured by the scope of the inquiry, only 1.7% of the companies in the sector of mechanical engineering made complete statements about changes of their master data. The growth of master data is shown in the following figure.

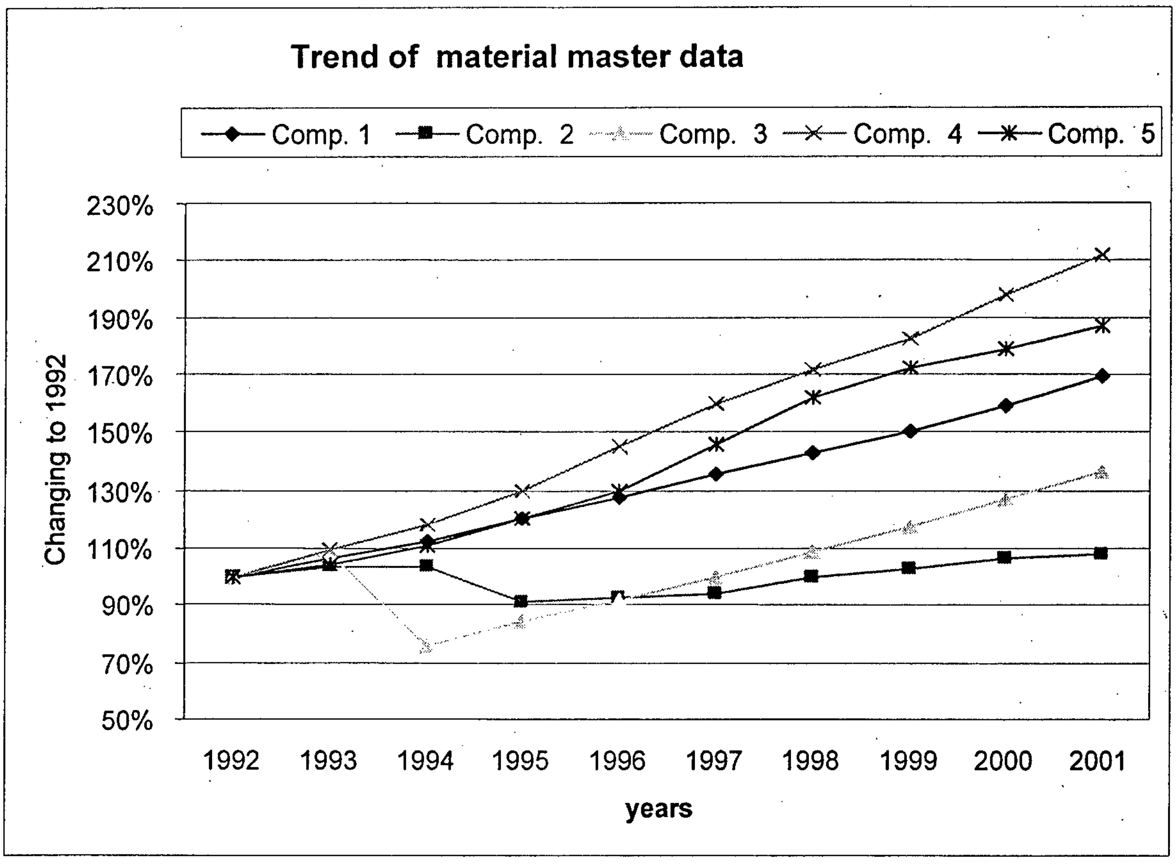

Figure 62: Growth of master data in five companies out of mechanical engineering

How figure 62 shows the master data in company 2 and 3 decrease in one year. This development can be attributed in both cases to the deactivation of former active master data. The following list brings out the average growth rate of master data in the five companies.

Company 1: 6.05%
Company 2: 0.81% (2.24%)
Company 3: 3.48% (6.31%)
Company 4: 8.69%
Company 5: 7.17%

The in brackets set values show the average growth rate per year without a consideration of the deactivation of former active master data in company 2 and 3. Even though such measures can make a worthy contribution to improve the operativeness of a part number information system and reduce the costs of maintenance the remaining active master data. But this measure is only a kind of aftercare and the effectiveness is depending on the number of master data, which can be set inactive. The here discussed in-company standards whereas can be implemented in the product development process and work against a high part growth in a preventive way.
Looking at the five companies it comes out that except company 2 the growth rate is between 6% and 9%. In which way this interval gives a realistic illustration of the average part growth in companies and can thus used as an indicator within the complexity management, should be asked critically in the face of the response rate. Furthermore it seems that the problem of a high complexity plays an important role in the calculation of the decision makers in these five companies and adequate organisational and structural measures have been prefaced to limit the part growing to a passable dimension. So the made growth rates can be interpreted as a lower bound for the average part growth in the sector of mechanical engineering.

One reason for the initiation of this project is that a complete and coherent approach to in-company standardisation can seldom be observed in practise. This is why the optimum standardisation mix for the competitive strategies of cost leadership and differentiation is developed in the next chapter. The findings provided in chapter 7 will be sufficiently general and can be applied in different industrial sectors.

Summary chapter 6

In this chapter the results of an empirical inquiry regarding the use of in-company standards and the meaning of complexity management in companies were discussed. It was shown that in-company standards come into operation in various companies and according to this of high importance. With the rise in annual turnover there is a clear tendency to standardisation experts in companies. A reason for this can be seen in the higher degree of specialisation, with clearly defined areas of responsibility and tasks in larger companies, which enables standardisation issues to be dealt with centrally. Compared with foregoing surveys, the 11-% rate of return is relatively low. Several explanations can be offered for this phenomenon. Firstly, in most small companies the problem was finding a suitable contact person capable of answering all questions. Secondly, the information requested was not available in all companies. For instance, only five companies in the sector of mechanical engineering gave comprehensive statements on the development of master data. Only few decision-makers seem to have noticed the potential of such key data for reducing an increase in costs or for noticing erroneous trends at an early stage and thus initiating suitable countermeasures in order to strengthen the competitiveness of companies.

Another aim of the company inquiry was to gain insight into the extent to which company-specific and product-specific features can be valid indicators of the effects of company standards on business success. Product-specific features (selling price, expected useful life or innovation loops) have been compared with in-company standards such as size range or unit assembly systems, modularisation, platform concepts or the extensive use of identical and repeat parts. A remarkable result in this context was that complexity management is most significant for products with a selling price of over € 100,000. Platform concepts played a significant role in only a few companies. This result is understandable if we consider the fact that the use of platforms determines numerous technical product features. Products that are based on platforms should have the following features in general: the technical solutions contained in a platform should be well-engineered. The existence of fundamentally new technical solutions regarding specific functions should appear only rarely. Furthermore, as many variants with identical primary product features as possible should be constructed on a single platform. In comparison with other in-company standards the extensive use of identical and repeat parts is relatively easy to implement. Even the small influence of company and product specific features on the benefit of this method certainly has a share in the general acceptance and popularity.

Another objective was to gain information on the average part growth in companies. In all, only five companies were ready or willing to provide the information requested. It transpired that the growth rate of parts was between 6 and 9 per cent, except in one company where the growth rate was lower. Overall the calculated growth rate is noticeably higher than the data contained in older studies.

7 The optimum standardisation mix

In this chapter an optimum standardisation mix will be developed following on from the description of in-company standards and their impact on competitive strategies together with an analysis of those factors specific to products, companies and markets that have a significant influence on the mode of operation of in-company standards. This optimum standardisation mix will juxtapose the in-company standards with the functional strategies ascertained from the research and development, procurement and production areas. A critical evaluation will be carried out as to how far the functional strategies can be supported by in-company standards. There will also be a brief summary of identified specific factors for products, companies and markets. This will be followed by a matrix illustrating the optimal standardisation-mix for the competitive strategies of cost leadership and differentiation. The results will be discussed afterwards in a rigorous critical analysis of the respective influencing factors.

7.1 Determinants of the success of in-company standards

In the chapter about in-company standards various factors having a significant influence on the success of standards were specified. Classification by the specific product-, company- and market-specific factors was then carried out. The following list is a summary of these identified factors and serves as the foundation of a critical analysis for the assessments included in the optimum standardisation mix.

Product-specific factors

- Technical complexity of the products (p1),
- Value of the parts used (p2),
- Cost price level (p3),
- Expected useful life of the product (p4),
- Quantity of tangible and intangible goods used in the production process (p5),
- Level of design costs (p6),
- Number of product versions (p7),
- Level of scaling detail (p8),
- Occurrence of identical functions in different products or versions (p9),
- Long innovation loops for primary product functions (p10),
- Number of safety-relevant functions (p11),
- Level of ecological damage caused by emissions during manufacture, utilisation and disposal of the product (p12).

Company-specific factors

- Automation level in production (c1),
- Share of production in the value-added process (c2),
- Number of production stages – vertical range of manufacture (c3),
- Importance of integrated information processing for business management and technical production tasks (c4),
- Share of procurement in the value-added process (c5),
- Importance of a secure supply of materials – multiple sourcing (c6),
- Outsourcing of tasks to the supplier in the area of design (c7),
- Annual amount of waste arising and resulting cost of its disposal (c8),
- Energy requirements in the value-added process (c9).

Market-specific factors

- Shifting of demand preferences (m1),
- Heterogeneous utilisation within the different customer segments with regard to later application (m2),
- Purchasing power or financial resources in the various customer segments (m3),
- Quality demands of customers (m4),
- Generation of ecological awareness and demands in the various customer segments (m5),
- Importance of susceptibility to failure for the purchase decision (m6),
- Importance of easy maintenance for the purchase decision (m7),
- Importance of short delivery times for the purchase decision (m8),
- Flexibility of product attributes as a criterion when purchasing (m9),
- Importance of a specified performance feature of a product function for the purchase decision – an elastic purchasing pattern with regard to the respective characteristic feature of a product function (m10),
- Quantity of data flows to preliminary and downstream enterprises as well as to other business units or production locations (m11),
- Dependency on other enterprises (m12).

7.2 Explanatory notes on the structure of an optimum standardisation mix

In order to obtain a clear illustration of the factors mentioned here, each factor in the standardisation mix has been assigned an unambiguous alphanumeric code. The success effect of in-company standards and functional strategies is determined by the particular characteristic of these factors or conditions. Thus the codification in the standardisation mix is shown by upwardly or downwardly vectored arrows. An upwardly vectored arrow signals that the success effect of the in-company standard or the respective functional strategy increased by a significant factor, and vice versa. If for instance products are designed which facilitate greater economies of scale in the production process, the success effect of a class list of

subject characteristics having identical functions in various products increases (p9 ↑), whereas there should be as few options as possible for outsourcing construction tasks (c7 ↓). When appraising the success effect of in-company standards on functional strategies, factor features may appear to be identical or even in opposition. Such constellations are shown in the standardisation mix in the respective cell in a bold font if the factor has a direct influence on ranking.

Five symbols are used to rate the impact of in-company standards on functional strategies in the standardisation mix:

- (+ +) shows a very positive effect;
- (+) shows a positive effect;
- (o) shows a neutral effect;
- (-) shows a negative effect;
- (- -) shows a very negative effect.

In this connection, several different valuations can result. In such cases the sequence of the symbols indicates the likelihood that the effect will occur. The ranking (o;-;+) thus means that in most cases the standard has a neutral impact on the respective functional strategy. However, in some cases the impact may well be negative, or under certain conditions even be positive.

7.3 The optimum standardisation mix for the competitive strategy of cost leadership

In the optimum standardisation mix for cost leadership, seven in-company standards are juxtaposed with eleven functional strategies from the areas of research and development, procurement and production. The results shown in the chart will now be discussed in detail.

Class lists of subject characteristics / feature lexicon
Class lists of subject characteristics are created primarily to describe objects (such as parts, assembly groups, or components) used in the value-added process. In the field of research and development in particular, they present a convenient instrument to ensure a high rate of repeat, identical and standard parts in still-to-be designed products. With a reduction of complexity in terms of a reduction in parts, the procurement and production processes can be standardised and good learning effects realised. Thus the impact of class lists of subject characteristics on a functional strategy, which aims at economies of scale, is very positive.
The efficiency of a repeat / identical product-part search using class lists of subject characteristics increases with the number of identical functions or variants of the various products (p9 ↑). The cost-reduction effect of this functional strategy also increases as the product-specific factor becomes more pronounced. Thus the p9 factor is an important criterion for the efficiency of class lists of subject characteristics within this functional strategy. In contrast to this, there are various requirements concerning the market specific

The optimum standardisation mix for a competitive strategy of cost leadership								
		Class lists of subject c. / feature lexicon	Numbering / part information systems	Size range systems	Unit assembly systems	Modularisation	Quality management systems	Environmental management systems
		p1 ↑, p4 ↓, p6 ↑, p9 ↑, p10 ↓, c7 ↓, m1 ↑, m8 ↑	p1 ↑, p6 ↑, p9 ↑, c4 ↑, c7 ↑, m1 ↑, m11 ↑	p6 ↑, p7 ↑, p8 ↑, p10 ↑, c7 ↓, m1↓, m6 ↑, m10 ↓	p3 ↑, p9 ↑, c2 ↑, c3 ↑, m2 ↑, m3 ↓, m8 ↑, m9 ↑	p3 ↑, p4 ↑, p10 ↓, c2 ↑, c3 ↑, m7 ↑, m8 ↑, m9 ↑	p11 ↑, m4 ↑, m6 ↑, m7 ↑, m12 ↑	p12 ↑, c8 ↑, c9 ↑, m5 ↑, m12 ↑
R. & D.	Products with high economies of scale in fabrication and procurement: p7 ↓, p9 ↑, c2 ↑, c5 ↑, m1 ↓	(++) **p9 ↑**, m1 ↑↓	(++;+) **p9 ↑**, m1 ↑↓	(+;o) p7 ↑↓	(++;+) **p9 ↑**, c2 ↑	(+) c2 ↑	(-;o)	(-)
R. & D.	Development of processes for cost reduction in fabrication and distribution: p9 ↑, c2 ↑, c3 ↑, m11 ↑	(+) **p9 ↑**	(+) **p9 ↑, m11 ↑**	(+;o)	(+) p9 ↑, c2 ↑, c3 ↑	(+) c2 ↑, c3 ↑	(-;o)	(-;o;+)
PROCUREMENT	Reduction of procurement and storage costs: p2 ↑, p5 ↑, c5 ↑, m11 ↑	(+;++)	(++;+) **m11 ↑**	(o;+)	(+)	(++)	(o;-)	(-;o;+)
PROCUREMENT	Efficient handling of order transactions: p5 ↑, m 11 ↑, m 12 ↑	(+)	(++) **m 11 ↑**	(o;+)	(+)	(+;o)	(o) m12 ↑	(-) m12 ↑
PROCUREMENT	Securing of material provision for the production process: p5 ↑, c1 ↑, c2 ↑, c6 ↑	(+)	(+)	(o;+) c2 ↑	(+) c2 ↑	(+;++;o;-;- -) c2 ↑	(o)	(o;-)
PRODUCTION	Reduction of changeover activities: p7 ↓, p9 ↑, c2 ↑, c3 ↑	(+) **p9 ↑**	(+) **p9 ↑**	(+;o) p7 ↑↓	(++) **p9 ↑**, c2 ↑, c3 ↑	(+) c2 ↑, c3 ↑	(o)	(o)
PRODUCTION	Shorter changeover times: p9 ↑, c2 ↑, c3 ↑	(+) p9 ↑	(+) p9 ↑	(+;o)	(o) p9 ↑, c2 ↑, c3 ↑	(+) c2 ↑, c3 ↑	(o)	(o)
PRODUCTION	Reduction of volume of stocks: p2 ↑, p5 ↑, p9 ↑, c2 ↑, c3 ↑	(+) p9 ↑	(+;o) p9 ↑	(+;o)	(+) p9 ↑, c2 ↑, c3 ↑	(++) c2 ↑, c3 ↑	(o)	(o)
PRODUCTION	Reduction of defective goods: p2 ↑, p12 ↑, c1 ↑, m4 ↑	(+)	(o)	(o;+)	(+)	(o;+)	(++) **m4 ↑**	(+) **p12 ↑**

factor (m1 ↑↓) since the benefit of class lists of subject characteristics is higher if customer demand shifts quickly and new product innovations become necessary (m1 ↑). But to achieve greater economies of scale, continuity in customer preferences is necessary (m1 ↓) because such a market condition facilitates an ongoing learning effect. Compared to the importance of factor (p9) in realizing economies of scale using class lists of subject characteristics, factor (m1) is of a lesser importance[143].

A high rate of repeat / identical parts within the product range is advantageous to the development of cost reduction processes. Thus, for example, machines having comparatively low flexibility, which are, however, characterised by very low production costs, can be used in production. Furthermore, a smaller range of parts reduces the complexity of the procurement and distribution process. In this context, being able to supply spare parts quickly can be particularly important. On the other hand, the characteristic of the product specific factor (p9) is of great importance.

The high rate of identical and repeat parts resulting from the use of class lists of subject characteristics has a positive effect on procurement and storage costs because the parts can be ordered in larger quantities and consequently, lower purchase costs can be negotiated with the supplier. Furthermore, less storage space would be needed[144]. If the use of class lists of subject characteristics leads to a higher share of standard parts in new products, its impact on this functional strategy will be very positive. In this way considerable saving potentials can be achieved.

Class lists of subject characteristics can even increase the efficiency of order processing since any reduction in the range of parts produced is accompanied by a decrease in the number of orders processed.

Any reduction in the variety of parts produced also reduces the likelihood of production downtimes caused by bottle-necks in the material supply chain. A large proportion of standard parts enables a company to access a number of potential suppliers (multiple sourcing) which in turn helps secure the supply of materials.

The number of changeovers can be reduced sustainably by having a small range of parts. In this connection a strong parameter value of the product specific factor (p9 ↑) holds a positive advantage for the class lists of subject characteristics as well as for this functional strategy.

The time taken for a changeover depends on the complexity of the conversion operation to be undertaken. Hence using parts with identical dimensions and features reduces the time and expense of necessary changeover. The influence of class lists of subject characteristics on this functional strategy is therefore also positive.

[143] See also the statements on Porter's convexity hypothesis in Chapter 2.5.1 of this work.
[144] The level of saving when storage space is eliminated is shown on pages 89ff. of this work.

One way in which capital can be freed is by reducing the level of back up stocks. A high rate of standard parts facilitates this functional strategy because the purchasing prices of standard parts are significant lower than those for drawing parts, for instance. Moreover, a reduction in the range of parts normally lowers the amount of capital bound up in back up stock.

In general, standard parts are technically well-engineered and therefore have a low reject rate. As the names imply, identical / repeat parts are already used by the company and therefore a certain degree of experience already exists regarding the handling of these parts together with a correspondingly low reject rate. Thus in this case, too, a positive impact of class lists of subject characteristics can be noted.

In summary, it may be said that class lists of subject characteristics have a constant, positive impact on functional strategies and hence sustainable support for a competitive strategy of cost leadership in the areas of research and development, procurement and production.

Numbering / part information systems

Numbering / part information systems are classification systems which govern the administration of and access to technical information. Whereas numbering systems identify all the relevant information within the value-added process by means of unique number, part information systems facilitate the search for standard, bought-in or drawing-board parts. Against this background, part information systems fulfil an important function, similar to numbering systems, in the search for parts, assembly units and components The impact of numbering and part information systems on functional strategies thus indicates a high degree of correspondence with class lists of subject characteristics.

Using parts, assembly units and components that are already contained in other products of the company is an important step towards developing products with greater economies of scale in the procurement and production processes. In particular, part information systems support the search for such parts in the design process, which make them particularly suitable for this functional strategy. A large number of identical functions in various products or their variants (p9 ↑) again reinforces the impact of part information systems on functional strategies.

The development of processes to reduce costs in production and distribution is simplified when there are a relatively small number of parts. The influence of part information systems on this functional strategy is once again positive. Besides the criterion of a large number of identical functions in different products (p9), the mass of data flowing to upstream and downstream companies and other business units or production locations is of great importance (m11 ↑).

The design of numbering systems in particular is very important for the reduction of costs for procurement and storage. Once again, the mass of data flowing to upstream and downstream companies and other business units or production locations is a determining criterion (m11 ↑).

A common problem encountered during the expansion of production capacity, e.g. after takeovers or mergers, lies in the different systems used for numbering identical parts. This hampers the bundling of demand and the release of possible synergy effects in procurement.

The efficiency of the order process is positively affected by functional numbering and part information systems. In the first instance, increased order volumes are responsible for this effect which results from the consistent numbering of parts. Furthermore, there is a decrease in the number of order transactions and, consequently, cost savings.

A reduction in the range of parts and the standardisation of item numbers together decrease the complexity of processes in the provision of materials thus securing their long-term supply to production.

An increase in the share of identical technical solutions and assembly parts in various products generally leads to a reduction in the number of changeovers. A fundamental requirement is once more a number of identical functions in various products (p9 ↑).

The work steps necessary for a changeover and the setup time needed are normally reduced if the products have a similar structure.

A reduction of inventory in the production process offers another option to set capital free. The unified effect of numbering and part information systems on the range of parts is to raise the volume of production lots and at the same decrease the relative storage period of material.

The recourse to parts assembly groups or components already used in the existing production range is particularly simplified by a functional parts information system. The existing figure based on experience for the handling of repeat / identical parts lowers the risk of improper handling and that of a high reject rate. Another reason for a low reject rate is the high level of stability of repeat / identical parts.

The impact of numbering and part information systems on functional strategies of cost leadership is generally positive and similar to class lists of subject characteristics. These positive features of numbering and part information systems are the result of the simple search for repeat / identical parts in the design process.

Size range systems

The use of the size range principle is aimed at reducing the workload during the design process. On the basis of the described similarity laws, products with the same functions can be produced in different size graduations both quickly and cheaply. The question as to what extent the size range products facilitate economies of scale in procurement and production depends on the scaling chosen. If the use of the size range principle reduces the number of

variants in comparison to the number of "conventionally" designed variants, then lower part complexity will have a positive impact on processes in procurement and production. Otherwise they may have a neutral effect on these processes. Looking at the use of size range systems to obtain greater economies of scale in procurement and production, it seems that the number of different product versions is ostensibly an inconsistent criterion (p7 ↑↓), because economies of scale are based on a small product range and a high rate of repetitive work steps. However the benefit of size range systems in terms of reducing construction work grows with the number of product versions. In this connection, the objective of size range systems must be taken into account. This is to reduce the number of variants by choosing suitable scaling.
This objective is of great relevance if the impact of size range systems on functional strategies has to be estimated. Where the use of size range systems is obtained through a reduction in the number of variants, there will be a positive influence on every functional strategy illustrated in the standardisation mix. If the size range principle is used primarily to reduce the design costs, there is more a neutral effect on functional strategies.

Unit assembly systems

Unit assembly systems serve predominantly as an instrument to reduce the variety of parts by dividing the technical product functions into a few standardised assembly groups. With the primary aim of reducing parts, unit assembly systems are well-fitted to achieving economies of scale in procurement and production. A basic requirement for the implementation of unit assembly systems is once more the product specific criterion (p9 ↑) (as many identical functions in different products as possible).

The development of processes to reduce costs in production and distribution is also positively influenced by unit assembly systems. In this context, particularly the late assembly time must be stressed because it allows production of individual assembly groups in highly automated processes. Furthermore, process complexity and cost structure in distribution are reduced with lasting effect.

In most cases the use of unit assembly systems is accompanied by a reduction in the variety of parts. Therefore fewer different parts and materials have to be procured and warehoused[145].

The number of order transactions to be carried out generally decreases with the standardisation of parts and materials. The higher utilisation rate resulting from standardisation makes larger procurement lots possible und improves the company's bargaining position.

The reduction of part and material complexity simplifies the material flow in the value-added process und ensures the provision of materials to the production sector.

[145] The effect on costs when saving on storage space is shown on pages 46ff. of this work.

The components of a unit assembly system are characterised by a high reutilisation rate of various products. Furthermore, products which are based on a unit assembly system have a late 'freezing point'. Thus specific components can be produced in large lots regardless of the order situation, which leads to a lasting reduction in the number of changeovers in the production process. In this context, a large number of identical functions can be seen as positive.

While unit assembly systems have a positive impact in terms of reducing changeovers, any reduction for the remaining changeovers is not directly obvious.

The high utilisation rate in different products generates a constant demand for identical components in the production process. This promotes a stable planning environment to work out the production program and makes stock reduction possible by means of better determination of production lots.

The reduction in variety of parts connected with larger production lots reduces the number of changeovers. This results in a drop in reject rates that occur during the start-up phase after each changeover.

Modularisation

Whereas the main objective of unit assembly systems is the reduction in the range of parts, the main objective of modularisation is targeted on a reduction in system complexity. A cutback in the range of parts is connected with greater economies of scale in procurement and production achieved through modularisation, too, even if only in a weakened form. Thus modularisation has at least a positive effect on the functional strategy for the realisation of greater economies of scale in procurement and production.

The fitting of the respective modules into a basic element or platform in the production process is comparatively easy owing to the fact that standardised interfaces can be fitted with a minimum of technical skill. This issue allows the implementation of efficient production processes that optimise the cost structure in production.

Modular products offer numerous options for reducing costs within the value-added process. In the development and design fields, tasks are often transferred to so-called system suppliers who provide the company with modules during the entire life cycle of a product. This close integration between company and supplier affects the choice of location, too. For instance, suppliers settle in the immediate vicinity of companies to ensure cost savings and a stable, just-in-time or just-in-sequence, supply of modules.

The close interconnection between module supplier and respective producer leads generally to a focus on a few capable suppliers (single sourcing). Thus the remaining order transactions are well integrated and, from a cost standpoint, optimised.

Through the long-term relationships with a small number of suppliers a generally high learning effect results and guarantees the provision of modules. Against this background, the impact of modularisation on this functional strategy at least, is, positive. The guarantee of material supplies for production is significantly influenced by the reliability of the module producer because close integration makes a short-term switch to other sources almost impossible. So, if a module supplier has a delivery bottleneck, modular product structures could have an extremely negative impact on the material procurement of a company.

The centralisation of several functions in one module normally reduces the assembly work and the number of changeovers also decreases.

The existence of standardised interfaces reduces the number of necessary changeover operations at the production facilities used and thus shortens the set-up times.

The functional strategy of material reduction in the production process is supported by modular products, in a sustainable way. In this connection, in particular the options of a time or sequence controlled material provision is important.

A direct impact of modular products on the reject rate is not ascertainable. In this context the advantage of having an uncomplicated disassembly of modular products which facilitates the quick change of faulty modules is worth mentioning.

Quality management systems

Internal measures taken to implement a quality management system can be very different from each other due to different organisational and process structures within a company. An absolutely objective appraisal of the impact of certified quality management systems on functional strategies is thus not always possible.

The development of products with greater economies of scale in procurement and production is not positively affected to any significant degree by the implementation and certification of a quality management system. If a quality management system shortens the innovation loops of products or components, e.g. to guarantee high-grade functional feature, the influence may even be negative.

In companies which place high demands on product quality the processes in procurement and production are principally focused on this aim. Targeting the development of processes for cost reduction is of secondary importance in the context of quality management.

The effects of a quality management system on procurement costs cannot be clearly assessed and are therefore considered to be neutral. However, warehousing costs can increase if the quality management system calls for higher (and more expensive) warehouse standards.

The extent to which the efficiency of order transactions is positively influenced by a quality management system also cannot be clearly estimated. This fact applies even to the following functional strategies. The implementation of a quality management system has a very positive impact only in terms of a reduction in the reject rate. Even though this objective is not explicitly defined in a quality management system, the compound effect of all the measures together leads to a lower reject rate in general. With an increase in demand for quality in the respective customer segments (m4 $\uparrow$) the importance grows for the company's success of both this functional strategy and the importance of quality management systems.

Environmental management systems

The development of environmentally-friendly products and processes plays a central role in an environmental management system. To keep the environmental sustainability of products at a high level, the continuous development of products from an environmental standpoint is necessary. Through this, the innovation loops are shortened with the consequence that the realisation of greater economies of scale in procurement and production is made more difficult.

The development of processes to reduce costs in production and distribution is not an environmental management target. Focussing on processes which cause as little environmental emission as possible often has a negative effect on the cost structure in production and distribution. Nevertheless, there are many examples to be found in literature which document measures in environmental management as having a cost-reducing effect on processes in the production and distribution[146].

From the viewpoint of costs, the arrangement of processes in procurement and warehousing on the basis of environmentally-relevant criteria can lead to less than optimal results. But in some cases the compatibility of ecological and economic aims is also possible in these sectors, so that under certain circumstances measures with the aim of increasing the ecological quality of processes can also lead to significant cost savings.

A high level of ecological quality of the production factors used within the value-added process is of great importance for environmentally-conscious companies. Against this background, a cost efficient handling of order transactions is of less importance. In fact there is a willingness to accept higher procurement costs for the supply of ecologically- friendly materials.

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[146] See also the examples on environmental management listed in this work on p. 104ff.

In exceptional cases, doing without raw materials and supplies which have inferior ecological features can lead to a decline in the supply of materials. In particular the appearance of new assessments of raw materials and supplies calling for an ecological revaluation may lead to the exclusion of a material from the value-added process which can hamper the procurement of materials with substitute features.

The effect of environmental management systems on functional strategies in production is, in most instances, neutral. One exception is the influence on the reject rate in companies because the production of faulty products pollutes the environment unnecessarily. In this connection, the level of pollution during the manufacture, utilisation and disposal phase of products is a decisive (p12 ↑), product-specific criterion for this functional strategy and for the importance of an efficient environmental management system.

7.4 The optimum standardisation mix for the competitive strategy of differentiation

Class lists of subject characteristics

The success of innovative products is determined, last but not least, by a rapid implementation of the constructive guidelines. In this context class lists of subject characteristics are an appropriate instrument. Development time can be shortened effectively particularly through a reduction in the design costs. From this standpoint, the effect of class lists of subject characteristics on the development of innovative products is positive. The use of class lists of subject characteristics to search for repeat / identical parts can, however, lead to less-than-optimum solutions, whereby the possibility of making distinctions between the product features is limited.

The use of class lists of subject characteristics for the development of environmentally-friendly products and processes brings significant advantages only in exceptional cases. In such cases, they have to include data concerning the ecological quality of the parts or components in addition to technical product data.

The use of class lists of subject characteristics ensures that a high number of identical, repeat and standard parts are used in products thus decreasing susceptibility to failures.

Their use is based on the documentation of existing technical product data. In contrast, research activities in the field of advanced technology are aimed at discovering fundamentally new technical solutions. For this reason class lists of subject characteristics hamper the flexibility of the research activities in this sector.

Recourse to existing technical solutions can shorten the research and development time required. In this connection two factors are of great importance for the success of both this functional strategy and of class lists of subject characteristics. On the one hand the length of innovation loops concerning primary product functions should be kept as short as possible (p10 ↓) because this increases the advantages of class lists of subject characteristics when searching for repeat / identical parts. Furthermore, customer preferences should also be more dynamic (m1 ↑).

The development of products that can be produced quickly and flexibly is supported by the use of class lists of subject characteristics, too. With the use of repeat / identical parts, time savings result through the creation of work schedules and NC-programs. A large number of identical functions in different products (p9 ↑) is in this case an advantage. The use of class lists of subject characteristics has no significant impact on a functional strategy that has the objective of increasing the quality of raw materials und supplies.

A high rate of repeat / identical parts leads generally to a decrease in the range of parts and consequently to more flexibility in procurement.

The impact of class lists of subject characteristics on functional strategies, which are derived from a differentiation strategy, is comparatively slight. Merely the production of qualitative high-grade products can be influenced positively by the use of repeat / identical parts because of their low susceptibility to failure. The inclusion of already-existing work schedules and NC-programs also reduces a potential source of error in the production process.

Numbering / part information systems

Part information systems primarily support searches for repeat, identical and standard parts. During the construction process of new products they help to achieve time advantages that accelerate the development of market-ready products.

There is no recognizable positive or negative influence of class lists of subject characteristics on the development of environmental friendly products.

The development of products with low susceptibility to failure is supported by reverting to technically proven parts and solutions.

The primary application of part information systems is in the search for existing technical solutions and for parts already being used in the production range. Research activities in the field of advantage technology aim at the development of fundamentally new technical solutions. Thus the use of part information systems with a restricted choice of parts can have a negative impact on this functional strategy.

The optimum standardisation mix for a competitive strategy of differentiation								
		Class lists of subject c. / feature lexicon	Numbering / part information systems	Size range systems	Unit assembly systems	Modularisation	Quality management systems	Environmental management systems
		p1 ↑, p4 ↓, p6 ↑, p9 ↑, p10 ↓, c7 ↓, m1↑, m8 ↑	p1 ↑, p6 ↑, p9 ↑, c4 ↑, c7 ↑, m1↑, m11 ↑	p6 ↑, p7 ↑, p8 ↑, p10 ↑, c7 ↓, m1↓, m6 ↑, m10 ↓	p3 ↑, p9 ↑, c2 ↑, c3 ↑, m2 ↑, m3 ↓, m8 ↑, m9 ↑	p3 ↑, p4 ↑, p10 ↓, c2 ↑, c3 ↑, m7 ↑, m8 ↑, m9 ↑	p11 ↑, m4 ↑, m6 ↑, m7 ↑, m12 ↑	p12 ↑, c8 ↑, c9 ↑, m5 ↑, m12 ↑
RESEARCH & DEVELOPMENT	Gaining advantages through differentiation by means of innovative products: p1 ↑, m1 ↑, m10 ↑	(+;o;-) p1 ↑, m1 ↑	(o;+) m1 ↑	(-;- -) **m1 ↑↓, m10 ↑↓**	(+)	(+)	(o;+)	(+;o)
	Development of ecologically friendly products and processes: p12 ↑, c8 ↑, c9 ↑, m5 ↑	(o;-;+)	(o)	(-)	(+)	(+)	(o)	(++) **p12 ↑, c8 ↑, c9 ↑, m5 ↑**
	Development of products with a low susceptibility to failure: p1 ↑, p3 ↑, p4 ↑, p11 ↑, m6 ↑, m7 ↑	(+) p1 ↑; p4 ↑↓	(o) p1 ↑	(++;+) **m6 ↑**	(+) p3 ↑	(+;++) **p3 ↑, p4 ↑**, m7 ↑	(++) **m6 ↑**, m7 ↑	(o;-)
	Research in the field of advanced technology: p10 ↑, m1 ↓, m4 ↑, m10 ↑	(-;o) p10 ↑↓ , m1 ↑↓	(o;-)	(-) p10 ↑, m1 ↓, **m10 ↑↓**	(o;+)	(o;+) p10 ↑↓	(+) m4 ↑	(o)
	Shortening of research and development time: p1 ↑, p10 ↓, m1 ↑, m8 ↑	(+;++) p1 ↑, **p10 ↓, m1 ↑**, m8 ↑	(+;++) p1 ↑, **m1 ↑**	(++) p10 ↓↑	(-;o) m8 ↑	(+;o;-) p10 ↓, **m8 ↑**	(o;-)	(o;-)
	Development and construction of products that ensure fast and flexible fabrication: p9 ↑, m8 ↑	(+) **p9 ↑**, m8 ↑	(+;o) **p9 ↑**	(+)	(+) p9 ↑, m8 ↑	(+) m8 ↑	(o)	(o)
PROCUR.	Quality enhancement of raw materials and supplies: p3 ↑, p4 ↑, c1 ↑, c2 ↑, m4 ↑, m6 ↑	(o) p4 ↑↓	(+;o)	(o) m6 ↑	(o) p3 ↑, c2 ↑	(o) p3 ↑, p4 ↑, c2 ↑	(++) m6 ↑	(+;o;-)
	Higher flexibility in the field of procurement: c2 ↑, c6 ↑, m12 ↑	(+)	(+)	(o)	(o) c2 ↑	(-) c2 ↑	(-) m12 ↑	(- -) m12 ↑
PRODUCTION	Higher flexibility in the production process: m1 ↑, m8 ↑	(o) m1↑, m8 ↑	(o) m1↑	(+;o) m1↑↓	(+) **m8 ↑**	(+) **m8 ↑**	(o)	(o)
	Reduction of throughput time: p2 ↑, c3 ↑, c5 ↑, m8 ↑	(o) m8 ↑	(o)	(o;+)	(++) **c3 ↑, m8 ↑**	(++) **c3 ↑, m8 ↑**	(o)	(o)
	Fabrication of high-quality products: p3 ↑, p4 ↑, p11 ↑, m4 ↑, m6 ↑	(+;o;-) p4 ↑↓	(o)	(+;o;-) **m6 ↑**	(+) p3 ↑	(+) p3 ↑, p4 ↑	(++)	(+;o;-)

The effect of part information systems on research and development is comparable to that of class lists of subject characteristics and hence is rated as positive. In this connection rapidly changing customer preferences (m1 ↑) are again an advantage.

Fast and flexible production is furthered where there are a large number of repeat / identical parts in newly-developed products. The degree of emphasis of the product specific factor should be as high as possible (p9 ↑).

The quality of raw materials and supplies can be positively influenced by the use of part information systems if this criterion is taken into consideration when searching for parts.

The reduction in the range of parts simplifies the procurement of raw materials and supplies and therefore increases flexibility in this area.

The effects of part information systems on functional strategies in production are similarly slight and may be regarded as neutral, as in the case of class lists of subject characteristics.

Size range systems

Size range systems offer the opportunity to develop sequential designs to various scales from an existing basic design through the application of similarity laws. They are an efficient instrument for rationalisation in development, design and production. The re-use of technically similar solutions can reduce the design costs significantly. The size range principle is counterproductive for the realisation of differentiation advantages in the development of innovative products because the technical structure of sequential design is carried over from the basic design. Hence similarity laws have a restrictive influence on technical innovation. The negative impact of size range systems on this functional strategy is furthermore clarified by two contradictory factor characteristics.
Products which are developed and designed using the size range principle have fixed, pre-set capability characteristics depending on the chosen scaling. If customer preferences are changing quickly there is the risk that the fixed bundles of product features will fail to find acceptance by the market. From this standpoint, customer preferences would have to show distinct characteristics (m1 ↓). But, for the success of innovative products rapidly changing customer preferences are advantageous (m1 ↑). Furthermore, product features based on a size range principle would need to be of subordinate importance with regard to making a purchase decision because these capability characteristics cannot be customised (m10 ↓). When it comes to making a purchase decision, the success of innovative products or product features rises (m10 ↑) with the importance of the respective capability characteristic of a product function.

From the ecological point of view, products which are based on the size range principle often have less-than-optimum characteristics because ecologically-reasonable modifications cannot be applied due to their derived nature and consequently fixed product structure.

With regard to freedom from interference, design based on the size range principle offers the advantage that the interdependencies between the parts or components are known, thus guaranteeing product stability. Here the significance of low susceptibility to failure should be of great importance when making a purchase decision (m6 ↑).

As a result of the restrictive guidelines regarding the product structure, the use of the size range principle is not suited to research in the advanced technology sector. Another disadvantage is found in the various characteristics of the market specific factor (m10 ↑↓).

We associate a sustainable shortening of the time required for research and development with design based on the size range principle. Hence the impact of size range systems on this functional strategy is very positive.

The similar structure of products and components based on the size range principle facilitates fast and flexible production.

The use of the size range principle has no significant impact on processes and functional strategies in the procurement area.

The limitation of variety caused by graded capability characteristics reduces complexity and thus increases flexibility in production.

The reduction in the range of parts makes larger production lots possible and reduces the average processing time of products.

The production of high quality goods can be supported by size range systems if the criterion of low susceptibility to failure (m6 ↑) is correspondingly significant. Where the characteristics of single product features are given emphasis, products based on the size range principle tend to have more negative attributes because a lot of technical characteristics are unchangeable.

Unit assembly systems

If a product is based on a unit assembly system, this is already an innovative differentiation advantage because customers can combine units and product functions according to their needs. Technical innovations can be integrated economically by exchanging a unit in a product already owned.

Unit assembly systems have a positive impact on the development of ecological friendly products and processes because the exchange of single units can increase the functional features successively and the expected useful life of the products is extended. This postpones the point at which a product is finally disposed of, thus reducing its environmental impact.

The development of products with a low susceptibility to failure is supported by unit assembly systems. In particular the opportunity to substitute faulty units expeditiously and cost-efficiently should be stressed.

To what extent unit assembly systems have an impact on research in the advanced technology sector depends on company-specific features and is thus assessed as neutral. Once more the option of an uncomplicated change of single units has to be stressed whereby an upgrade of products already in use with fundamentally new technical solutions is simplified.

The development of products based on unit assembly systems is normally connected with a great deal of design effort, so that more time may be needed for research and development.

In particular a late freezing point ensures a fast and flexible production process for products which are designed using the unit assembly principle.

The direct effects of unit assembly systems on procurement are not obvious and are therefore rated as neutral.

Flexibility in the manufacture of products is disproportionately high if the product is based on a unit assembly system. Production in large quantities and a late freezing point are primarily responsible for this. The importance of short delivery times when making a purchase decision should be made as distinct as possible to increase the benefit of this functional strategy and of unit assembly systems (m8 ↑).

Unit assembly systems are conducive to a sustainable shortening of processing time in the production. Behind this lies mainly the continuous demand for units, which makes the highly-automated production of individual units possible. This advantage increases with the number of production stages or existing vertical range of manufacture (c3 ↑) in the company. Furthermore, the market-specific factor should here be as distinct as possible (m8 ↑).

Even in the production process of qualitatively high-grade products such unit assembly systems can be important. The two reasons for this are the ease of maintenance and the broad, individual application spectrum.

Modularisation

The impact of modularisation on functional strategies is in many cases comparable to that for assembly systems. Hence the following statements relate only to those cells within the matrix with varying results.

Modules are connected with a product platform by means of necessarily detachable interfaces. So in the event of occurring a fault a rapid exchange is possible. This guarantees an above-average operational availability of modularised products. The positive influence of modularised products on this functional strategy increases with the cost price level (p3 ↑) and the expected useful life of the respective product (p4 ↑).

The development and design of modularised products generally involves a great deal of work. However the producers have the option of outsourcing tasks in the area of research and development to their suppliers. Such outsourcing allows activities in research and development to run parallel to each other (simultaneous engineering) and can thus shorten the time needed in these areas. Against this background, the impact of modularised products on this functional strategy is mainly positive. The effect of short delivery times on the purchase decision should have a great influence in this connection (m8 ↑).

Modules are technically complex components. Hence for an efficient production of modules the respective supplier must have the necessary know-how and suitable manufacturing facilities. Against this background, only a few companies are able to supply such modules. The relationships built up between producer and module supplier are distinctly interdependent and symbiotic by nature. A shift to a new module supplier involves great risk and is in the short-term seldom possible. Hence the production of modularised products hampers flexibility within procurement.

Quality management systems

Depending on the existing objectives and their implementation, the use of quality management systems can have diverse effects on the value-added process. If an aim is to produce technically high-grade product functions, then the innovative activities can be supported by a quality management system.

Quality management systems primary serve the implementation of quality aims. Hence the impact of quality management systems on the ecological compatibility of products and processes cannot be assessed.

A low susceptibility to failure is an important quality criterion for products. As the implementation of a quality management system is closely associated with this aim, the impact of quality management systems on this functional strategy is very positive.

Furthermore, the importance of quality management systems increases with the significance of a low susceptibility to failure in the purchase decision (m6 ↑).

Quality management systems can be of great importance even during research in the area of advanced technology. This is particularly the case where the relevant product features can be improved to influence a purchase decision.

In this respect, compliance with high quality standards involves careful construction techniques and is associated with time-consuming tests during the development phase of new products.

The impact of quality management systems on the development of products which can by produced expeditiously and flexibly is marginal and hence is considered to be neutral.

Within the area of procurement, quality management systems have a positive bearing on the quality of raw material and supplies.

The use of high quality standards reduces the number of potential suppliers and so cuts back on flexibility in terms of multiple sourcing.

The impact of quality management systems on functional strategies in production in terms of greater flexibility and a shortening of processing time are rather low. Indeed the production of qualitative, high-grade products is a core task within a quality management system.

Environmental management systems

The development of innovative products can be supported by environmental management systems. This is the case, if innovations improve the ecological product features.

The primary objective of environmental management systems lies in the ecological arrangement of the value-added process. Products and processes connected to their production and distribution particularly come under this category. In this connection, four factors are of great importance for success. With an increase of environmental pollution through emissions created during the manufacture, utilisation and disposal phases, it becomes increasingly necessary to take into account all the ecological considerations when producing goods (p12 ↑). Other arguments for the implementation of an environmental management system are the large quantity of waste created and high waste-disposal costs (c8 ↑). Also production processes with a high energy consumption amplify the demand for efficient environmental management systems (c9 ↑). The creation of ecological awareness in the various customer segments is another criterion of particular relevance (m5 ↑).

Environmental management systems can have no significant impact on the development process of products with a low susceptibility to failure. In fact the ecologically-motivated avoidance of certain raw material and supplies can increase the susceptibility to product failure. This can also extend to the time spent on research and development.

Research in the field of advanced technology and the development of products that can be produced flexibly is not significantly influenced by environmental management systems.

The effects of environmental management systems on the quality of raw materials and supplies deserve a differentiated approach. The effects on ecological quality are certainly positive. But the quality connotation includes even more criteria such as expected useful life, stability and general function and usage properties which may be insufficiently fulfilled by an ecologically dominated procurement.

High ecological demands on raw materials and supplies as well as the production process of the respective suppliers serve to constrict flexibility during procurement.

With the exception of qualitatively high-grade products, environmental management systems have no significant influence on production. Furthermore, various interpretations of the term quality prevent clear statements from being made concerning this functional strategy. If ecological quality is of great importance, there is a positive impact of environmental management systems on this functional strategy.

Summary chapter 7

In this chapter, the optimum standardisation mix for the competitive strategies of cost leadership and differentiation is set out. Class lists of subject characteristics have a constant, positive impact on functional strategies of cost leadership. A similar positive impact can be attributed to numbering and part information systems. Even size range, unit assembly systems and modularisation have predominantly good characteristics in terms of cost leadership strategies, while the impact of quality and environmental management systems on these functional strategies is fairly neutral. As far as functional strategies derived from a differentiation strategy are concerned, the impact of class lists of subject characteristics is comparatively slight. The effects of part information systems on these functional strategies are also fairly slight. The impact of size range systems on the respective functional strategies of differentiation vary considerably and range from very positive to very negative. Unit assembly systems, modularisation and quality management systems have in most cases a positive impact. Except for the development of ecologically friendly products and processes the influence of environmental management systems on functional strategies of differentiation are in most cases neutral.

8 Summary and outlook

Research carried out for this study has shown that through the selective use of in-company standards, competitive strategies and derived functional strategies can be facilitated in the long term. The concluding chapter will give an overall view of the fundamental results of this study before other research options are discussed.

8.1 Summary

The aim of this study was to analyse the impact of in-company standards on competitive strategies. To do this, definitions of the relevant professional terminology were given in the introduction. Following on from this, two different typologies of competitive strategies were described together with an examination into their suitability in terms of the working steps to be undertaken (second chapter). In particular, Porters typology was selected for the use in this study because it excludes hybrid strategies and enables the derivation of functional strategies stemming from competitive strategies. The exclusion of hybrid strategies has been proved to portray a simplified and even fuzzy illustration of reality. But in consideration of the existing advantages this issue is of secondary importance. In the third chapter, functional strategies and general objectives were established for the competitive strategies of cost leadership and differentiation in the corporate divisions of procurement, research & development and production. Attention focused on these three corporate divisions for the following two reasons: On the one hand in-company standards have the greatest impact on competitive strategies in these divisions. On the other hand this research issue has only rarely been addressed in the literature so far. The fourth chapter shows in-company standards that have a significant impact on competitive and functional strategies. In the fifth chapter some examples from industry are given to clarify the economic significance of in-company standards. In the sixth chapter the results of an empirical inquiry concerning the use of in-company standards and the importance of complexity management in companies are discussed. The inquiry has shown that in-company standards come in numerous companies into operation and according to this are of high importance. With the increase of the annual turnover there is a clear tendency to experts in standardisation. A reason for this can be seen in the higher degree of specialisation with clear scopes of competences and tasks in bigger companies, which facilitate a central handling of questions concerning standardisation. The rate of return of 11% is in comparison to former inquiries relative low. For this purpose several reasons can be mentioned. In mostly small companies was the problem to find a suitable contact person, who could respond to all questions. Even the information asked for were not in all companies available. For example only five companies in the sector of mechanical engineering made comprehensive statements concerning the development of master data. The potential of such key data to reduce an increase of cost or notice early erroneous trends and start suitable counteractive measures to strengthen the competitiveness of companies seems only noticed by few decision-makers. In the seventh chapter, the optimum standardisation mix for the competitive strategy of differentiation and cost

leadership is set out. The optimum standardisation mix enables the appraisal of the impact of in-company standards on functional strategies in consideration of product, company and market specific factors and hence is a novel compact and capable instrument for the strategic use of in-company standards.

The operations laid down in the Grant Agreement, Annex I, have all been accomplished and can be assigned to the following chapters:

Working Step I	Chapter 2, 5, 6
Working Step II	Chapter 3
Working Step III	Chapter 4
Working Step IV	Chapter 7

8.2 Outlook

The results of this research work show that a strategic use of in-company standards can improve the competitiveness of companies with a lasting effect. But in several areas some research is still necessary.

In particular, research activities with the aim of deriving functional strategies from competitive strategies must be intensified to ensure a complete and coherent argumentation covering all strategy levels. Apart from the detailed results of Müller-Stewens and Lechner, this is lacking in the German literature. Even the Anglophone literature exhibits a lack of current research results that deal with this point.

Experience gained from interviews with decision-makers in various companies has shown that many managers still underestimate the negative impact of a great variety of parts and components on the cost structure of the value-added process. Existing literature concerning this subject matter is often out of date and the methods employed in calculations are mostly hard to follow. As a result, the data loses in value so that it is not possible to create a sufficient level of awareness amongst management. This clearly shows the need to acquire new, current data. One step in this direction was the attempt to acquire new data on the average part growth in companies by sending out a questionnaire. The results obtained from this item are based on the statements of five companies and give little more than an overview of the current situation in the field of mechanical engineering. Our experience and the information received give rise to the assumption that data in other industries does not always agree with the results and statements of this inquiry. This attempt may therefore be viewed as a first step. In order to obtain detailed key data on the average part growth in other industries, it will be necessary to conduct a comprehensive inquiry to close this gap in future. This task is of high importance and requires some input of effort and in the first instance good relations to companies to obtain the information needed. Another important task in this research field lies in the identification of the costs connected with the registration of a new part in companies. Existing published data on this process are often old and the method of calculation is often not explained in detail. Furthermore, this survey was limited to in-company standards in the field

of development and construction. The significance of other in-company standards, such as those for special services or for the management and exchange of documents and data, did not form part of this inquiry. Hence an extensive analysis of standards in this field is justifiable. In-company standardisation is of central importance for the reduction of process and part complexity. But other functional strategies can also be supported by the targeted use of in-company standards. In particular, the nearly continuous positive effects of unit assembly systems and modularisation on functional strategies of differentiation and cost leadership, as shown here, are important arguments for an intensified use of in-company standards.

To what extent the results of this work facilitate the strategic use of in-company standards within enterprises will be shown in future developments. Overall it can be said that the optimum standardisation mix enables the impact of in-company standards on functional strategies to be appraised in terms of factors specific to product, company and market and is therefore a novel, compact and capable instrument for the strategic use of in-company standards. By reading this report, even persons with a marginal knowledge in this field will have an opportunity to appreciate the strategic potential of in-company standardisation for the competitiveness of companies. It is hoped that the new evidence and ideas provided will enable numerous companies to utilize in-company standardisation profitably and to successfully master the current competitive conditions.

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